So You Want To Be An Instrument Technician?

A brutally honest and somewhat irreverent guide to a career in industrial instrumentation and control

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Chapter 1

Disclaimers and caveats

Hi – my name is Tony, and I have worked in and around the field of industrial Instrumentation for over 30 years, 11 years as an instrument technician within three different industries and the rest as an instructor of that same subject at Bellingham Technical College. And no, that is not a photograph of me on the cover – rather, it's one of my former students doing contract instrumentation work at an oil refinery in Louisiana.

During my decades working in and teaching this career, I have seen many things and have learned many important lessons. Some of those lessons came as a result of direct experience, some from observing the experiences of others. My goal in writing this guide is to share some of this practical experience with you in the hope that you will find within this career all the challenges and rewards it has to offer.

No amount of experience makes anyone an expert on *everything*, and so you should know some of the limitations and biases of my advice. To understand these limitations and biases, it is necessary to know a bit more about the author.

This guide is written from the perspective of someone who has only been employed as a *technician*, not as a scientist or an engineer. It also comes from the perspective of someone who received most of their education outside of any classroom: my first foray into the world of technology and engineering was growing up on a small farm where my millwright father taught me the basics of construction, welding, electricity, and machine maintenance. This was a place where he and I built experimental wind turbines and solar water heaters, and designed our own metal lathe from scrap parts. It was also a place where both my parents strongly supported self-education, purchasing for me electronic kits from Radio Shack and later a personal computer (before the IBM PC or Apple MacIntosh even existed). Our home library was well-stocked with an encyclopedia set, an array of technical books spanning aircraft piloting to electrical engineering, and overseen by parents who respected the power of the written word. My home library and home workshop were halls of learning far more engaging than any classroom at public school, although I was fortunate enough to have many good teachers who did what they could within their limited schedules and budgets to fuel the fire of a young boy's curiosity about all things scientific. These experiences taught me in a very personal way the value of hard work and self-study, the importance of doggedly pursuing *understanding* in a world that can be crushingly indifferent to individual wants and needs.

As much as my childhood taught me the value of personal effort, it also taught me the value

of community support. Outside of my immediate family there were multiple teachers in the public school system who helped kindle my curiosity and love of learning, and they did so well beyond the requirements of their teaching contracts. From my fourth and fifth grade teachers who started up an Electronics Club at my elementary school in the late 1970's, to my freshman Biology teacher in high school who set up a "special topics" class just so I could have a chance to learn about and repair some of the high school's scientific test equipment, to my junior and senior Physics instructor who gave practical context to the abstract calculus concepts I encountered in Math class, to the Automotive and Metal shop instructors who supported my special projects at every turn, these educators[1] showed me what can happen when people identify a need and help their fellow people meet that need. These weren't just teachers doing their jobs – they were *educators* committed to fostering their students' growth.

An unusual community-based educational opportunity came to me in 1996 when I first encountered the Linux computer operating system – software designed to emulate the functions of commercial Unix operating systems – created by an online community of volunteer programmers and Unix enthusiasts, provided entirely free of cost to whomever wished to download and use it. This was the first time I had witnessed the spirit of community learning and amateur design culminate in such a powerful and useful *product*. The GNU General Public License gave all users of Linux software legal permission to view the "source code" and learn from the developers' work, while also ensuring all future versions would remain just as free and "open" as the version received. Linux not only provided me with an opportunity to expand my knowledge of computers, but it also struck me as a community-based model applicable to much more than computer software.

When I entered the technical career field in 1987, it was in the form of a maintenance position at a small machine shop in Yakima, Washington. This was a part-time job for me (25 to 30 hours per week) concurrent with my studies at a private technical school where I was enrolled in an Instrumentation program. Here at this shop I had opportunity to learn about machine tools (lathes, mills, grinders, welding machines, electrical discharge machining) as well as the digital control of those machines. My immediate supervisors[2] were wonderful people, challenging me with technical tasks appropriate to my knowledge and skill levels, and giving me invaluable work experience which paved the way for future employment. They also provided a forum for me to share what I knew about electricity and electronics with fellow co-workers, setting up an informal classroom to use once a week. It was my first real experience teaching, and it was beneficial to me as well because it helped sharpen my own understanding of what (I thought) I knew while expanding the knowledge base of co-workers who were completing an ambitious project (linking a modern Japanese CNC control computer to a legacy American milling machine).

My next career steps took me to an oil refinery, and then to an aluminum smelter. Working in "big industry" was an altogether different experience than the small machine shop. There was still plenty to learn and to do, but notably minimized was the open forum of shared knowledge – instead, I more often encountered people reluctant to share what they knew because they believed "knowledge hoarding" was necessary for their own job security. A noteworthy exception to this sad rule was the Instrumentation shop at the aluminum smelter where I found an unusually supportive and tight-knit group of technicians who looked out for each other. There was also a small group of process control computer programmers who freely shared information with me at the smelter, but

[1] Listed in order: Don Dineen (4th grade), Bill Charleston (5th grade), Frank Hebert (9th grade Biology), Dick Shelley (11th and 12th grade Physics), Wes Kentch (Automotive Shop), and Bill Roberts (Metal shop).

[2] Thanks to Mark Cleary (Foreman) and Dale VanTrease (Supervisor), who were wonderful mentors and friends.

an alarming number of the other technical tradespeople and engineers were not interested in helping anyone else learn anything about their job. Time and time again I saw the "knowledge hoarders" foiled while the supportive community of my fellow instrument technicians served to help all of us.

When I made the career switch from hands-on technical work to full-time teaching in 1998, I found the same sharp distinction among my fellow teachers: some were helpful and open to sharing with me anything they knew about their subjects or about teaching in general, while others were "knowledge hoarders" of the first degree. The college environment proved to be no different from industry when it came to the merits of supportive community: those who were willing to share what they knew with others found that same sentiment reciprocated to their own benefit, while the knowledge-hoarders stagnated to their own peril. There may be a time and a place for knowledge-hoarding on the job, but I sure haven't seen it.

Taking this moral lesson to heart, I soon found opportunity at the college to apply the open-source spirit of Linux to a different type of product development: the writing of technical textbooks. For the remainder of my teaching career I have continued writing open-source books primarily for the benefit of my students, and secondarily for the benefit of anyone outside of my classroom walls who desired to learn about these topics. The world is full of people both young and old desiring to learn what I wanted to learn as a child, and if I could place these free resources in their hands I figured it would help make the world a better place. Multiple co-workers at the college initially warned me against making my writings free and available for public download, their reasons ranging from weakening my own job security to losing potential income. Almost two decades later I'm happy to report numerous job offers extended to me as a result of freely publishing these textbooks. Those critics, on the other hand, no longer work in public education.

The years spent teaching at the college level has been nothing short of eye-opening. At this point I have literally taught several hundred students, and given the structure of technical courses at the college where I teach this means spending approximately one full academic year with each and every one of my graduating students. What I've seen in terms of attitudes, aptitudes, career success, and career failure has been most instructive and serves to inform most of the opinions you will read in this guide. The single most important lesson I have learned in my teaching career is that *attitude is everything*. This applies to instructors and school administrators every bit as much as it applies to students: people who pursue learning with determination and integrity achieve wondrous results; people who regard school as just another job, or just another obstacle to overcome will be lucky to meet their goals.

Readers familiar with my other writings[3] will note some stylistic differences in this guide. In my other works I strive for objectivity and precision, while here I will be far more colorful and opinionated. The subtitle pretty much says it all: *"A brutally honest and somewhat irreverent guide to a career in industrial instrumentation and control"*. Enjoy what you find here, take advice where it is useful to you, and my best wishes go to you in your pursuit of this challenging and rewarding career.

[3] *Lessons In Electric Circuits*, *Socratic Electronics*, *Lessons In Industrial Instrumentation*, the *Modular Electronics Learning Project*, etc.

Chapter 2

What in the world is Instrumentation?

This is a very good question, and it is the rare individual who knows the answer(s). For being such a fascinating and lucrative career, not to mention being essential to any industrialized society, hardly anyone knows what an Instrumentation is. Certainly you don't find young children saying they want to work as instrument technicians when they grow up.

Simply defined, Instrumentation is the practical application of technologies to the problem of *measurement and automatic control*. Accurate measurement is obviously important for all commercial and scientific ventures, and automatic control is vitally important to efficient operation of industrial processes. Instrumentation as a career takes several different forms, many industries employing multiple categories of instrumentation practitioner, some of them listed here (in no particular order):

- **Metrologists** – people tasked with maintaining precise calibration standards, used to ensure the accuracy of measuring devices
- **Engineers** – people responsible for designing measurement and control systems for industrial use, including development of novel processes and procedures to answer technical challenges
- **Designers** – people who select, plan, and document the infrastructure of measurement and control systems, including connection panels, cables, tubes and pipes, and support structures
- **Programmers** – people who develop software for digital control systems such as DCSs (Distributed Control Systems) and PLCs (Programmable Logic Controllers)
- **Technicians** – people who install, maintain, troubleshoot, and upgrade all manner of measurement and control systems
- **Fitters** – people who install and replace tube and pipe connections associated with measurement and control systems

Each of these job categories require specialized learning, typically formal education for two to four years, but often followed by on-the-job learning for many more years. Sub-specialties exist within each of these categories, too. Metrologists, for example, may specialize in a particular type of measurement since each one has its own standards, foundational knowledge, etc. A metrologist working in an electrical standards laboratory has a very different job than a metrologist specializing in measuring mechanical stress on aircraft wings, and both of these are different from a metrologist working in a chemical testing laboratory. Some engineers require four years of schooling, and others only two (although state licensure for engineers requires a full four-year accredited Baccalaureate degree in engineering). Engineering jobs also widely vary in terms of scope: some engineers find themselves on the cutting edge of new product development, while other engineers' jobs consist of routine project management and employee supervision[1]. Some technicians specialize in working with just one type of instrument (e.g. a control valve technician) while others work with every type of instrument at one facility. Some technicians do design work requiring substantial creativity, while others' tasks are narrowly defined[2] by industry-specific regulations (e.g. the nuclear and pharmaceutical industries are famous for strictly defining and limiting skilled work tasks). Some instrument technicians double as industrial electricians[3], while others are never even permitted to perform work on electrical circuits above a certain (low) voltage level. This field is *diverse* if nothing else.

Practitioners of Instrumentation tend to share one common trait above all others: *they are problem-solvers*. This is a career that will constantly challenge you with new technologies, new regulations, new tools, while at the same time relying on a fundamental base knowledge of physics, chemistry, electricity, and other unchanging principles.

If this sounds interesting to you, then *read on*. The following sections in this chapter will illustrate some of the many industries employing instrumentation practitioners, with a strong emphasis on work as an instrument technician.

[1] This is a cautionary note for those considering engineering as a profession. Most of the engineers I have had the pleasure of working with enjoy their jobs. However, I have met more than a few who became disenchanted with their careers, expecting jobs characterized by constant work with technology and design and instead finding themselves placed in managerial roles for which they were neither interested nor suited.

[2] This is a cautionary note for those considering skilled craftwork as a profession. Beware jobs that limit your ability to exercise your full potential, to learn and to grow as a practitioner of your trade. Above all, do not expect a corporation to nurture you in any professional sense. In my experience it is rare to find an employer who takes an honest interest in developing the potential of their skilled craftspeople. As with most things in life, it is *your responsibility* to develop your career and to look for better opportunities.

[3] In the United States, such "dual-craft" work is an interesting intersection of a highly regulated trade (electrical) with a poorly regulated trade (instrumentation). Some states (e.g. Oregon) require dual-craft workers to possess the appropriate electrical license(s) to perform any work involving electrical signals or power, while other states (e.g. Washington) waive this requirement for work performed within the confines of an industrial facility. When I worked as an "I&E" (Instrument and Electrical) technician in the state of Washington, I knew nothing of state licensure requirements for electricians. As a consequence of my ignorance, I failed to make any effort in documenting my supervised electrical work, which I could have had validated as recordable hours recognizable by the state for the purpose of eventually obtaining my electrical license. This same company for which I once worked as an I&E technician has now adopted the policy of refusing to pay for their current I&E technicians to take National Electrical Code classes despite the fact that this training would improve their skills and lead to safer work practices. The rationale for this refusal is that doing so would make these technicians more valuable in the labor market, and so the best of them would have more incentive to leave for another job.

2.1 Electric power generation

An electrical *generating station* is a facility taking some form of energy and converting it into electricity for transmission to distance places of use. Many types of generating stations exist (e.g. hydroelectric, nuclear, solar, wind, coal-fired, natural gas-fired, geothermal, etc.) but most of them utilize similar equipment.

Most "thermal" generating stations use water as a medium for converting heat into electricity. Water is pumped under high pressure into a *boiler* where some heat source (fire, nuclear reactions, solar radiation, etc.) converts the water into vaporous steam. This high-pressure steam is then used to drive large steam engines (typically *turbines* consisting of a large rotating shaft with blades driven by the expanding steam), which drive electrical generators (consisting of a magnetized rotor spinning within an array of stationary wire coils, the action of the magnetic field inducing electricity in the wire coils). After releasing its energy to the generator, the steam now exists at a relatively low pressure. To complete the cycle, this low-pressure steam must be cooled by some heat sink (cooling tower, radiators, ocean water, etc.) so that it may condense back into water for re-injection into the boiler.

Instrumentation common to nearly all electric generating stations includes *revenue metering* for measuring how much electric power is being "exported" to the grid, *protective relaying* which monitors all electrical assets for faults which could lead to physical hazard and/or costly downtime, *vibration monitoring* for large rotating machines (e.g. generators, gearboxes, pumps, fans), as well as *regulatory* systems for maintaining stable electric voltage, current, and frequency values. Other instrumentation is more specific to the type of prime mover(s) used to turn the generators, and will be discussed in each subsection.

Electric power is an unusual commodity in that it is technologically difficult to *store* in large quantities. While grid-scale energy storage technologies are currently being researched and developed to meet this need, for the present time the lack of such storage means the supply of electricity must always match the demand for electricity at any given moment in time. Thus, generating stations must "ramp up" and "ramp down" their power output to ensure supply continuously equals demand. If supply exceeds demand, the electrical voltage levels will rise throughout the system with the possibility of damaging equipment. If demand exceeds supply, the voltage will "sag" to low values with the potential for the grid to "collapse" resulting in widespread black-outs. Some types of generating stations have the ability very quickly adjust their power output, while others (most notably, steam-based thermal generating stations) do not. Some generating stations operating from renewable energy sources such as sunlight and wind ramp up and down on nature's schedule, necessitating other generating stations be on the grid ready to complement them and thereby maintain grid stability.

2.1.1 Nuclear

Nuclear generating stations use a process called *nuclear fission* to "split" atoms of Uranium, Thorium, and/or Plutonium metal, generating large quantities of heat. This heat is used to boil water into steam, which is then used to drive turbine engines to spin electrical generators. Heat is shed through the use of cooling towers, the most common design being the self-drafting "hyperbolic" towers seen with large plumes of water vapor exiting their open tops.

This photograph shows an uncommissioned nuclear station located near Elma, Washington. The round concrete structure is the containment building for one nuclear reactor, while the red-colored rectangular building houses the steam turbines and generators. Cooling towers are not shown in this photograph:

Nuclear generating stations typically shut down every few years to refuel the reactors and discharge waste materials. These *outage* events are times of busy work, with contracted labor performing maintenance, replacement, and upgrades that are not possible during operation. Special certifications and clearances are required of workers entering nuclear facilities, which tends to limit the labor pool for such work and makes those personnel even more valuable.

Instrumentation used in nuclear generating stations includes *radiation monitors* for both reactor conditions and leaks into the environmental, standard steam boiler instruments (e.g. water level sensors, water pressure sensors, temperature sensors, flow sensors, water quality analyzers), control valves for throttling fluid flows, pump controls, control rod servos, instruments associated with emergency reactor coolant systems (e.g. pressure and temperature sensors, water level sensors, block valves), and material handling systems for new and spent reactor fuel bundles. Control systems are layered for "defense in depth" security of the reactor: a *regulatory* control system throttling reactor power according to demand on the electric grid, plus at least one *safety* control system tasked solely with shutting off the production of power under emergency conditions.

While nuclear power instrumentation is complex and highly redundant (for safety), the actual job for a typical instrument technician is somewhat routine. One might argue there are worse things in life than excitement at a nuclear station, but be warned that every task you would do while on the job at one of these places comes with a large quantity of "paperwork" documenting all steps taken. If having your every move checked and documented seems uncomfortably constraining, this might not be the job for you.

Employment at nuclear stations is heavily biased towards nuclear reactor specialists from the United States Navy. The US Navy offers some of the best nuclear reactor training in the world, as one would expect given their large fleet of nuclear-powered surface ships and submarines.

2.1.2 Natural gas

Natural gas is another source of energy for generating stations, and is the cleanest-burning of the fossil[4] fuels, emitting less carbon dioxide[5] and pollutants per unit of energy than any other naturally available fuel. Natural gas is a relatively easy "upgrade" from coal-fired generating stations, and is at the current writing the preferred method for backfilling[6] low production from renewable sources such as wind and solar.

The following photograph shows a natural gas power plant in Ferndale, Washington. It uses two General Electric gas turbine engines (similar in design to jet aircraft engines, only built to provide stationary power) and one steam turbine engine operating off of the waste heat from the exhausts of the two gas turbines. This design of power plant is called *combined cycle* because it combines two different forms of thermal-to-mechanical energy conversion in one operation. Furthermore, this particular facility sells its low-pressure steam to a neighboring industrial facility for increased energy efficiency and profitability, making it a *cogeneration* power plant:

Cogeneration power plants may be owned and operated by the same company utilizing the low-grade steam (e.g. an oil refinery which owns and operates its own power plant), or they may be owned and operated by a separate entity, perhaps the local electric utility or a third (private) party.

Instrumentation found in gas-fired generating stations vary according to their design. Combined-cycle stations require all the standard sensors and control valves one would expect in a steam-based thermal power plant, but the gas turbine has instrumentation specific to its own needs. Gas turbines are complex rotating machines, with many temperature sensors, flow sensors, pressure sensors, vibration monitors, servo systems for adjusting blade pitch, flame detectors for managing combustor operation, and valves and sensors for multi-fuel[7] operation.

[4] Fuels derived from ancient deposits of liquids and gases buried deep underground represent a re-introduction of "fossil" matter into the contemporary environment.

[5] CO_2 is a known "greenhouse gas" trapping solar energy in the Earth's atmosphere in the form of additional heat, which is a mechanism of climate change.

[6] A term often used in the US power industry to describe this use of backup power generation is "wind firming". In order to maintain stable balance between generation and consumption on any electrical grid, unsteady sources such as wind and solar must be balanced by some other reliable source capable of rapid scaling. Gas turbine engines fired by natural gas fuel work well for this purpose. As chemical battery technologies improve, we may see a shift toward grid-scale battery storage instead of "wind firming" with natural gas turbines so that 100% of the energy may in principle be derived from the renewable source with no reliance on fossil energy.

[7] Many gas-fired turbines may also run on jet fuel, diesel, kerosene, and/or other liquid fuels, which means these generating stations usually have liquid fuel storage and handling facilities so they may continue to operate for periods of time where the natural gas supply is unavailable.

Natural gas is a very clean-burning fuel, but harmful emissions are still produced by the turbine engines. One such emission is a class of compounds referred to as *oxides of nitrogen* (or NO_x) created when fuels are mixed with air and burned at high temperatures, especially in excess-air conditions such as those found within an internal combustion engine. Special analytical instruments called *stack gas analyzers* or *continuous emissions monitoring systems* (CEMS) are used to quantify the emissions of NO_x and other pollutants from the exhaust of a generating station. Catalytic reduction systems are used to reduce these NO_x emissions, typically using anhydrous ammonia (NH_3) as a reactant with the hot exhaust gas to reduce NO_x compounds to water vapor and elemental nitrogen. These "after-treatment" systems use instruments to monitor and control ammonia stores, flow rates, catalyst temperatures, and other variables necessary to mitigate NO_x emissions.

2.1.3 Coal

Coal remains a large percentage of the energy portfolio within the United States. It is a very energy-dense fuel, and may be burned at high temperatures to convert water into steam, which is then used to power steam turbine engines to spin electrical generators and produce electricity. As coal is not as convenient to transport as gaseous or liquid fuels, coal-fired stations tend to be located fairly close to coal mines for their fuel source. This also means the future viability of any coal-fired generating station is linked to the capacity of the mine.

In contrast to natural gas-fired generating stations, coal-fired stations are far dirtier, more complex, and maintenance-heavy. The sheer amount of skilled labor required to maintain and operate a coal-fired station is much greater than that of a comparable gas-fired station, not to mention the vastly greater environmental impact (more carbon dioxide per unit energy produced, plus arsenic, mercury, and radioactive materials ejected into the air from the mined coal). This means a coal-fired station is a much more interesting place to work, with more complex processes to maintain.

The following photograph shows the Antelope Valley station in Beulah, North Dakota:

Instrumentation used in coal-fired thermal generating stations include common steam-plant instruments plus a multitude of sensors and control devices used to manage the large conveyor systems feeding solid coal granules to the furnace(s) heating the boiler(s). *Weighfeeders* are one such instrument, used to measure the weight of solid material conveyed on a moving belt. Pollution monitoring and mitigation equipment is extensive at any coal-fired facility, with multiple instruments located on every exhaust stack to monitor emissions. One of the unique pieces of equipment commonly found at a coal-fired facility is an *electrostatic precipitator* which uses a wire grid charged with high-voltage electricity to attract dust particles (much like a statically-charged object attracts household dust) in order to prevent them from exiting the exhaust stack. Electrostatic precipitators require electrical controls for this high voltage, as well as control systems to sequence self-cleaning cycles.

The management of large quantities of solid, granular materials is always a challenge, and coal is no exception. The dust presents both a breathing and an explosion hazard, and is also very abrasive on machinery. Specialized equipment exists to transport and store coal, with its own instrumentation for monitoring of coal quantities and control systems for sequencing of machine actions.

An interesting use of coal applicable to electricity generation is *coal gasification*. Once a widespread source of manufactured gas for street lighting in the 1800's, this is a rather old technology which may see renewed use in the future. The principle here is that coal is heated to very high temperatures under oxygen-poor conditions, resulting in the release of carbon monoxide gas as well as other flammable compounds useful as fuel. Liquid fuels such as gasoline may even be synthesized from coal gas using chemical conversion processes such as the *Fischer-Tropsch* process. Other chemical compounds derived from the gasification of coal may be used as feedstocks for a wide range of industrial products including synthetic fertilizer.

The following photograph shows the Dakota Gasification plant in Beulah[8], North Dakota. Located near the Antelope Valley generating station, this facility is essentially a refinery for coal. It was originally designed to produce synthetic natural gas in the 1970's when natural gas prices were much higher than they are now. When natural gas prices fell, the plant continued to remain profitable by selling its other chemical products:

Modern coal gasification is one of the methods for *clean coal* utilization. While the term "clean coal" is mostly political (brandished by politicians wanting to appeal to regional economies dependent on coal extraction while maintaining the appearance of environmental responsibility), there is a significant amount of truth to the label. The conversion of solid coal into gas allows separation of its constituent compounds, and makes possible[9] the refining of those compounds for combustion with less harmful emissions. Carbon dioxide, a known "greenhouse gas", is much easier to separate and sequester in a coal gasification process than when it is found mixed with flue gases from a conventional coal-fired furnace. The Dakota Gasification facility, for example, captures the majority of carbon dioxide gas from the coal and exports it through pipelines for use in oil well injection.

Instrumentation is extensive in coal gasification processes. In addition to basic pressure, level, temperature, and flow measurement, special chemical *analyzers* are used to measure concentrations of specific chemicals within mixtures. Precise control of reactor conditions (especially temperature) is essential to long and safe operation, and there is currently research being done on completely new sensor technologies capable of greater measurement accuracy and reliability[10].

[8] An interesting note about this facility is its technical self-sufficiency. Touring the plant, I was frankly amazed at the technical competence of its skilled craftspeople and the capacities of its maintenance shops. The place was built to do *anything* they need on site without relying on outside assistance!

[9] So long as there is little or no market value added by performing this separation, power companies have no natural incentive to do this. Therefore, the extent to which any "clean coal" facility is *actually* clean depends on external factors such as governmental regulation.

[10] An example of this in the coal gasification industry is *optical interferometry* temperature sensors, which use pulses of light passed through sapphire crystals to sense the temperature of those crystals. The sapphire crystals are used as sensing elements within the gasification reactors, producing highly accurate and dependable temperature measurement.

Like coal-fired generating stations, coal gasification plants are maintenance-intensive and therefore expensive to operate. Their economic viability remains to be seen, especially in light of competing energy sources such as natural gas and renewables, the cost of which continue to decrease over time.

2.1.4 Hydroelectric

Hydroelectric generating stations use falling water to drive turbines and turn generators. Some very large hydroelectric facilities exist in Washington state, including the Grand Coulee Dam which at one time was the largest hydroelectric dam in the world:

While hydroelectric facilities are not without environmental impact, they emit no pollutants[11]. Hydroelectric stations are also relatively simple to operate and require less maintenance per unit energy produced than combustion-based generating stations.

Very large hydroelectric facilities such as Grand Coulee are operated by the federal government of the United States, and as such there exists a strong preference toward hiring military veterans. This tendency is quite typical of any federally-managed system or facility: to a federal government agency, military veterans represent a pool of prospective employees who are a more accurately "known quantity" due to the extensive documentation created during military service. Civilians, by contrast, are more difficult to assess in terms of background and reliability. It is also helpful for these employers to know that their prospective employees are able to work to schedules, follow instructions, and respect chains of command[12]: all tasks that happen to be essential to military service.

Instrumentation used within hydroelectric generating stations include *vibration monitoring* and *lubrication oil control* for the large water turbine and generator assemblies, reservoir water level measurement, servo systems for moving the *wicket gates* which throttle water to the turbines, motorized winch controls for spill gate movement, and a host of instruments associated with auxiliary systems.

[11] One might make the argument that production of the concrete used to construct a dam releases large quantities of carbon dioxide, but this is a one-time release rather than ongoing over the life of the dam.

[12] Interestingly, I have spoken with recruiters from some non-governmental employees who lament certain aspects of military conditioning. This seems especially true of high-tech startup companies looking to hire the most *creative* and *innovative* employees they can find. For all the good military experience seems to do in shaping a person's self-discipline and adherence to safe and proper procedure, the same regimented life can (in some cases, at least) have a detrimental effect one's open-mindedness.

2.1.5 Wind and Solar

Wind and **solar** generation together represent a fairly small percentage of worldwide electric power production, and much of this has to do with their sporadic nature. Solar energy production is curtailed by cloud cover, and ceases entirely at night. Wind does not cycle with daylight, but is nevertheless subject to its own unpredictabilities.

The following photograph shows wind turbines and photovoltaic solar panels in operation at the Wild Horse wind farm near Ellensburg, Washington:

Photovoltaic solar panels are nearly maintenance-free, and so require little in the way of skilled labor for ongoing operation. Wind turbines, by contrast, are machines operating under high stresses and therefore subject to wear and tear. Most work performed on wind turbines at the time of this writing, however, is done by personnel qualified by the turbine manufacturer because many electric utilities operate wind turbines under an ongoing maintenance contract from the manufacturer. This makes employment within the wind power field more challenging to secure because it relies on training and certifications specific to a manufacturer.

Instrumentation and controls for wind and photovoltaic solar generating stations are relatively simple, especially when contrasted against thermal generating stations. Wind turbine blades require pitch control, and of course there is vibration monitoring for the gearboxes and generators. Photovoltaic panels are so incredibly simple, there is little about which to measure or control. Some panel arrays use servo motor controls to track the sun as it arcs across the sky from morning to evening, but aside from that there is little instrumentation in a photovoltaic generating station in addition to the normal revenue metering, protective relaying, and voltage/current/frequency control.

An interesting variation on solar energy are *solar thermal* generating stations. These facilities use concentrating mirrors to focus sunlight on tubes carrying heat-transfer fluid, which then conveys the heat to water where steam is produced. The steam then drives turbines to spin generators as in any other thermal-based generating station. Some solar thermal stations use heat-storage media to continue generating electricity during evening hours, which is an interesting engineering solution to the problem of cyclic power production. One would expect the maintenance and operation demands of a solar thermal generating station to be comparable to that of any other thermal-based facility.

In the Department of Energy (DOE) photograph shown below, a circular array of tilting mirrors focuses sunlight onto a thermal collector mounted to the top of a tall tower. Pipes in the collector array carry heat-transfer fluid which convey the heat of the concentrated sunlight to a boiler system where water is turned to steam to drive turbines and spin electrical generators:

Thermal solar generating stations require much more instrumentation than photovoltaic-based solar generating stations. All the instrumentation you would expect for a steam-based thermal power plant is found here, plus additional instrumentation for managing the heat transfer (and/or heat storage) fluid: pressure sensors, level sensors, temperature sensors, flow sensors, throttling valves, and variable-speed pumps. Servo systems are used to tilt the concentrating mirrors in order to maintain consistent focus on the heat-collecting tower as the sun traces its daily arc across the sky.

2.1.6 Geothermal

Geothermal is another source of renewable energy upon which generating stations have been built. Like coal-fired stations, however, geothermal stations must be located near the energy source. This limits their locations to volcanically active regions. An interesting possibility for improving the economics of a geothermal station is to harvest valuable minerals from the hot water (called *brine*) taken out of the ground.

The following photograph, taken by Gretar Ivarsson and graciously released into the public domain, shows the Nesjavellir power generating station in Iceland:

Instrumentation found at a geothermal generating station of course includes standard steam-boiler sensors and actuators, plus additional instruments used to regulate the flow of *brine* to and from the geothermal wells. Heat exchangers used to transfer heat from the hot brine to pure water for making turbine-grade steam must also be closely monitored and controlled, as their performance degrades with metal corrosion over time. Differential temperature sensors and flow sensors together monitor the thermal power of these circulating fluid loops, while water quality analyzers monitor for heat exchanger leaks.

2.1.7 Future trends

It is hard to say exactly what the **future** holds for electric power generation, other than an increased portfolio of renewable sources and continued growth in general. Clearly, electricity has shown its unique ability to transfer energy over long distances with minimal losses (*far* better than any other known form of transport), and the increasing sales of electric passenger vehicles provides a new market for that energy. Advances in grid-scale **energy storage** is necessary for renewable energy sources to be viable as a replacement for fossil fuels, and these storage facilities will undoubtedly require skilled employees to design, maintain, and upgrade. Innovations in nuclear power such as Thorium-fueled fission reactors and **nuclear fusion** seem tantalizingly close, but at the time of this writing still lie well outside of commercial reach.

Whatever new sources of energy are tapped for electric power generation, you can be sure instrumentation will play a vital role in the safe and efficient management of these resources.

2.2 Electric power distribution

One electricity is generated, it must be transmitted over long distances and distributed to many points of use. This requires a large-scale infrastructure of power lines, substations, energy storage units, and other facilities, all of which require a high degree of skill to design, build, and maintain. The sum of all these facilities and components is called a *grid*.

One example of such a facility is an electrical substation, used to route electricity to different locations as well as change levels of voltage and current. A photograph of one such facility is shown here:

Both precise measurement and fast control are required for safe and efficient operation of an electric power grid. The terms used to describe these functions within a power grid differ somewhat from the terms used in other industries. Instead of calling it all *Instrumentation*, you will more likely hear terms such as *metering* (systems used to quantify the amount of electricity), *protection* (systems used to automatically shut off the electricity in the event of component failure), and *SCADA* ("Supervisory Control And Data Acquisition") systems used to provide remote measurement and control over long distances. All of these systems, though, utilize principles and technologies common to other forms of industrial instrumentation, which means they are relatively easy for an accomplished instrument technician or engineer to learn.

Another career path within the electric power distribution industry is the maintenance of high-voltage power lines. The following photograph shows one of my former students doing this work atop a high-voltage transmission line tower in Montana, working for the Bonneville Power Administration (BPA):

An important fact to consider when contemplating a career in the electric power industry is its relative immunity from economic cycles and outsourcing. Unlike manufacturing-based industries which may shutter under hard economic times or relocate to other countries with cheaper labor and lax environmental standards, power grids represent billions of dollars in irreplaceable capital investment. Wages and safety standards tend to be very high[13] as well.

[13] As an example of high wages, one large electrical utility I know of pays all overtime work at 200% the standard hourly wage (i.e. *double* time). This utility literally refers to this rate of pay as *high time*, referencing its origins as an enhanced pay grade for any work done by lineworkers above a certain elevation from ground level (now graciously extended to all skilled craftspeoples' overtime). Surveying the wages of protective relay technicians within another public utility revealed annual compensation near the $200,000 level (in the year 2016).

2.3 Water treatment

Every city above a certain threshold population must operate a collective system of water processing and distribution, because urban areas require plentiful potable water, fire suppression water, and sewage disposal. These water and "wastewater" systems are highly instrumented for efficient and safe operation, and thus provide another industry sector for instrument practitioners.

The following photograph shows a *clarifier* vessel at the West Point wastewater treatment facility in Seattle, Washington. This vessel utilizes gravity to separate solids from liquid in the wastewater prior to other forms of treatment:

An interesting feature of this particular wastewater plant is that it extracts *energy* from the sewage by separating solids from the water and then bacterially digesting those solids in an oxygen-poor chamber to release methane gas which may be used as a fuel. At the West Point plant this gas is used to power a set of internal-combustion engines to drive large water pumps. At some wastewater facilities this production of biogas is sufficient to power the entire operation with a net surplus of energy! The biological value of wastewater is not to be ignored either, with essential nutrients such as nitrogen, phosphorus, and many minerals present and available for plant fertilization.

In terms of job hazards, water treatment plants are relatively safe. Perhaps the most dangerous aspect of this industry is the widespread use of *chlorine* as a disinfecting agent for both potable water and treated wastewater. Chlorine gas is highly toxic, and for this reason is very good at killing bacterial life within water, but obviously this poses risks for workers operating and maintaining the chlorination systems. A modern trend is to seek alternatives to chlorine use and bulk storage of elemental chlorine, some wastewater treatment plants now using intense ultraviolet light instead of chlorine to disinfect discharged wastewater.

Instrumentation used within water and wastewater treatment facilities includes water turbidity[14] sensors, water pH sensors, residual chlorine concentration monitors, water temperature sensors, water flow sensors, vibration monitors for large rotating machines, and variable-speed motor controls for pumps. Wastewater treatment digesters have their own special needs for monitoring and control, including all of the previously-mentioned instruments plus gas safety valves, explosive gas monitors, and gas quality analyzers. Since water and wastewater treatment plants connect with all residences and businesses within a city, an extensive SCADA system conveys data between remote sites such as pumping stations and storage tanks.

[14] Turbidity is defined as the capacity of a liquid to scatter or block the passage of light. Clean water has low turbidity.

A daunting challenge facing wastewater operations at the time of this writing is the removal of pharmaceutical substances from wastewater. Clarification and digestion processes were originally designed only to handle organic materials, not synthetic compounds such as drugs and hormones. The monitoring and extraction of these potentially harmful substances presents an engineering challenge and a likely source of future employment as specialized measurement and control systems must be added as part of the solution.

Like the electric power industry, water and wastewater treatment systems represent huge capital investments and therefore must remain operational despite economic cycles. This translates into job stability for operations, maintenance, engineering, and management personnel. Wages and benefits also tend to be very good within this industry.

2.4 Petroleum and natural gas production

Commonly referred to as *upstream operations* in the petroleum industry, the exploration and extraction of crude oil and natural gas reserves is a major industry sector utilizing vast arrays of sensors and control systems.

The following photographs show a new offshore oil rig during dry construction (left) and an onshore oil rig undergoing drilling and "fracking" operations in Stanley, North Dakota (right):

Measurement and control systems are used at these facilities mostly for the physical variables of pressure, flow, and liquid level. Petroleum pumped from underground is a diverse mix of hydrocarbon oils, hydrocarbon gases and vapors, water, salt, and minerals which must be separated prior to further processing. *Separator* and *filter* vessels are the major process units here, the separators using gravity to differentiate gases from liquids, with level-sensing instruments used to monitor the interfaces between these compounds. Flow measurement is very important because it is the chief variable used to assign economic value to the extracted hydrocarbons. These flow-sensing devices are classified as *custody transfer* instruments because their data is used to transfer ownership of the hydrocarbons from one company to another (and also to record this physical transaction for the purposes of government taxation). A variety of automatic safety systems[15] monitor the wellheads and associated processes, and in the case of offshore rigs there exist a variety of utility systems (water treatment, electrical power generation, communications) necessary to support both the petroleum processes and the people working and living on the rig for extended periods of time.

The work environment for offshore production is unlike most others. Employees must travel to the rig by helicopter, where they live and work typically for two weeks at a time. Every other two weeks is "off time", which is equivalent to having a short vacation every month. This alternating work schedule combined with the need for constant travel is liberating in a certain way, as it allows employees to live wherever they wish during their time off. If you have two weeks off work every month and need to fly to get there anyway, why not just make your home anywhere you please?

Onshore oil work may be roughly divided into two categories: *drilling* and *production*. Drilling a new well is labor-intensive and the jobs cycle dramatically with the crude oil market. An onshore oil well is much smaller and requires much less capital investment than an offshore oil rig, and is therefore more easily abandoned when prices drop too low to justify further investment. When crude oil prices are high and a particular geographic area is open for development, the result is often a

[15] A very specialized piece of equipment for an oil well is something called a *blowout preventer* (BOP), whose function it is to clamp shut the pipe carrying high-pressure oil from a well in the event of a pipe rupture.

boom town where thousands upon thousands of workers descend on some patch of ground to do their work. This often leads to social disruption where small towns are suddenly overwhelmed with traffic and housing and law enforcement burdens they cannot possibly meet in time. Employees are often faced with the choice between living in a company-run *man camp*[16] or paying exorbitant prices[17] for what little housing is to be found in the town. If you ever find yourself with a job opportunity in a "boom town" area, know that compensation for housing costs is standard when negotiating terms of employment. Many skilled workers new to the oil field environment are not aware of this fact, and many employers are more than willing to let that new employee discover their limited housing options *after* they've signed the contract!

[16] A "man camp" is pretty much exactly what it sounds like: a set of barracks housing all the oilfield workers, mostly men. Rules and regulations for life in a man camp are quite strict, the penalty for breaking those rules being expulsion from the camp.

[17] I visited Stanley, North Dakota during the year 2012 when oil production in that state was "booming" and saw insulated shacks measuring 10 feet by 30 feet *renting* for $3000 per month!

2.5 Petroleum and natural gas processing

After oil and gas has been removed from the ground at wellsites or rigs, it must be further processed to make it usable as fuel. This processing is classified as either *midstream* or *downstream*: "downstream" being facilities such as refineries and "tank farms" used for storage, and "midstream" being intermediary processing units designed to prepare the petroleum for long-distance transport and refining.

An oil refinery exists to increase the market value of petroleum. Oil taken from the ground is both a poor fuel and a poor lubricant in its natural form and therefore worth relatively little as a commodity. Once chemically altered and purified into forms such as gasoline, jet fuel, kerosene, diesel fuel, lubricating oils, plastic feedstocks, however, petroleum commands a much higher price. Photographs of a typical oil refinery are shown here:

Oil refining consists of two major process categories: *separation* and *chemical reaction*. Separation typically takes the form of *distillation*, where petroleum is heated and then cooled in a vessel called a "distillation tower" or "fractionating tower[18]" where vaporization and condensation act to differentiate hydrocarbon compounds on the basis of boiling point (temperature). These separated compounds are then introduced into a variety of chemical reactors designed to process them into more valuable forms: turning heavy oils into jet fuel, tar into asphalt and other products, lighter oils into gasoline, etc. In most cases, additional stages of distillation follow each chemical reactor to separate desired products from unreacted feed compounds (the latter re-cycled through the chemical reactors to finally achieve conversion).

After separating, reacting, and re-separating the hydrocarbon compounds, the final step of oil refining is to precisely combine different compounds to create a salable product. Gasoline is a good example of this, being an intentional mixture of *hundreds* of different chemical compounds. This mixing process, called *blending*, is used to create fuels, lubricating oils, and a variety of other petroleum liquids.

Oil refineries are highly instrumented operations, with literally *thousands* of control "loops" monitoring and regulating variables important to the safe and efficient operation of chemical

[18] Looking at the two photographs on this page, we see a number of slender vertical structures rising high above the ground. Those structures that are open at the top are called *stacks*, while those structures closed at the top are called *towers*. Towers are just closed-end pipes situated in a vertical orientation, equipped with multiple platform "trays" inside of them where falling liquid droplets collect and rising gases bubble up through sieve holes. The counter-flow of hot rising vapors and cooler liquid droplets falling downward creates a process by which chemical compounds of different boiling point have opportunity to separate from other compounds and collect at similar levels within the tower.

processes. Practically every type of sensor in existence finds application within an oil refinery, and the control systems are quite complex: typically consisting of a mixed network of DCSs (Distributed Control Systems) and PLCs (Programmable Logic Controllers). In addition to "base-layer" regulatory controls, oil refineries often sport numerous safety control systems designed to bring the processes down to a condition of safety in the event of some emergency such as a spill or a fire. Oil refineries also use large quantities of *steam*, which mean they operate their own boiler systems, with all the instrumentation you would expect for such. With all this instrumentation in play, oil refineries are ideal facilities in which to experience intense exposure to a huge variety of measurement and control technologies. They also tend to pay their skilled laborers and engineers very well.

A chief disadvantage of oil refinery work is the inherent danger of the process itself: nearly every process fluid within a refinery is highly flammable, and the quantities stored are enormous. An interesting feature of the oil and gas processing industry is the necessity of periodic shutdowns called *turnarounds* where process equipment is taken out of service for maintenance and repairs that cannot be done online. Some refinery units, for example, require a turnaround once every three years. During these turnaround events, thousands of temporary jobs are created at that site, with skilled workers from around the country traveling to work for months at a time. Some instrument technicians make this their career: working from one turnaround to another.

2.6 Industrial chemical processing

At the risk of presenting a category that is too broad, a wide range of industries exist to process specific chemicals for other industries. Large-scale chemical processing is vital to modern life, as so many of the products we consume are manufactured from synthetic (i.e not naturally-occurring) compounds. This is true for clothing, for plastics of all types, for composite materials used in construction, for inks and dyes, for food additives, for lubricating oils, and a host of other applications you probably aren't even aware of. Specialty chemicals are the lifeblood of any modern economy.

One such chemical is *sulfuric acid*, which is so widely used in industry for a number of different purposes that economists sometimes gauge the vitality of a nation's industrial sector by the quantity of sulfuric acid per year utilized within its borders!

Photographs showing just two small portions of a sulfuric acid processing plant are shown here:

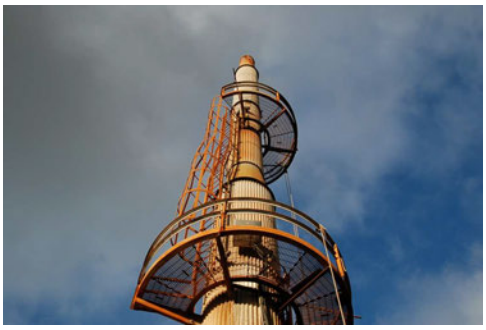
It is difficult to generalize on the instrumentation used within chemical plants, because it varies so much depending on the chemical(s) being processed. However, it is safe to say that chemical plants are generally as highly instrumented as oil refineries, which is to say that their instrumentation is *extensive*. Chemical reactors typically require precise measurement and control of pressures, temperatures, levels, and flow rates for efficient and safe operation. Distillation towers, used to separate mixtures of chemicals by boiling point and vapor pressure, require extensive sensor arrays and complex control algorithms to economize energy usage. Since many chemical processing operations harbor danger due to the toxicity of the raw and processed chemicals, safety system instrumentation is also typically extensive for these facilities.

Some of the most complex instruments in existence are *chemical analyzers*, used to quantity specific chemical compounds within a mixture or a solution. Analyzers tend to be very maintenance-intensive, requiring specialized knowledge and skill to maintain. This translates into high pay, as instrument technicians capable of doing this work are few in number[19].

[19] Another example of the Law of Supply and Demand in action: when a needed commodity (in this case, specialized skilled labor) is in short supply, its value becomes high.

As with most heavy industries, chemical processing usually involves releases of gases into the atmosphere. Tall stacks vent these gases far from ground level where they may pose immediate hazard to personnel working in the facility, but instruments and control systems are still used to measure and mitigate quantities of toxins. This is another application of CEMS (Continuous Emissions Monitor Systems) in industry.

The following photograph pair shows a typical exhaust stack at a chemical processing facility, as well as a small "shelter" housing the CEMS analytical instruments near the base of the stack:



2.7 Industrial air products

The air we breath consists primarily of nitrogen gas (approximately 78% by volume), secondarily of oxygen gas (approximately 21% by volume), plus argon (less than 1%), carbon dioxide, and trace concentrations of other gases. Each of these gases in their pure forms have value for industrial and medical purposes, and so an entire industry exists just to separate air into its constituent gases. Nitrogen gas is commonly used as an industrial *purging* medium to displace other gases and vapors[20], oxygen gas is used to enhance the breathing of people with lung conditions as well as used as an oxidizing gas to power certain types of metal welding processes, argon gas is chemically inert and often used as a "shield" gas for high-temperature arc welding processes, and carbon dioxide finds a spectrum of uses from beverage carbonation to arc welding shield gas.

What occurs at an air separation facility is mostly physics, and little chemistry. Separation of any mixture into its components may be performed by specialized filtration (down to the *molecular* level), as well as by *distillation* which is a common process in the petroleum and chemical industries.

Air separation plants also use gas compression and cooling to *liquefy* these gases for more economical storage and transport. Very high pressures and very cold temperatures are required to achieve liquefaction of elemental gases such as nitrogen and oxygen, and in fact the super-cold temperatures associated with these liquids bears its own unique adjective: *cryogenic*.

Photographs of a Linde air separation facility in Vancouver, Washington are shown here:

Instrumentation at an air separation facility is typical of any distillation plant, where pressure sensors, level sensors, temperature sensors, and flow sensors are all used to ensure proper separation of the different compounds from the mixture that is air. Special *analytical* instruments sample the separated streams to measure their purity, and this information is fed back to the control system in order that it may make adjustments to those measured parameters to maintain purity at the desired levels.

The air separation industry is somewhat unique in that 100% of its feedstock (air) is completely free of cost. Significant quantities of electricity[21], however, are required to drive the compression,

[20] Examples of nitrogen displacement include displacing explosive vapors in fuel storage tanks, as well as displacing atmospheric moisture from vessels containing sulfuric acid, using a nitrogen gas "blanket" occupying the space between the liquid interface and the vessel's roof

[21] This is a good example of the Second Law of Thermodynamics, which describes the natural tendency of matter

cooling, and distillation processes necessary to separate air into its elemental gases and liquefy them at cryogenic temperatures.

An associated industry is the manufacture of precise *gas mixtures* for calibration use in a wide variety of industries. These "calibration gases" are used as chemical *standards* for gas analyzers, to prove the accuracy of those devices.

toward homogeneity (i.e. toward an increase in *entropy*). Significant energy input is always required to undo any thorough mixture (i.e. to decrease the entropy of some localized region), and air separation is no exception.

2.8 Mining

The extraction of economically valuable minerals from the Earth is an ancient human endeavor, and continues as a large-scale industry today. Certain mining practices such as *strip mining* have proven to be highly destructive to natural habitat, but so long as the demand for minerals exceeds our ability to recycle them from products already existing, people will continue to extract these resources.

Some modern mines make use of hydraulic transport: mixing the ore with water to form a slurry, which is pumped to the surface through pipes rather than hauled in carts as in the days of old. With any mining operation there exists the technical challenge of separating the desired ore from the rest of the earthen material (called *gangue*). One common process for separating certain types of minerals is *froth flotation*, where the ore slurry is stirred and bubbled with large volumes of compressed air. Some of the minerals settle to the bottom of the flotation chamber, while others rise to the top to form a bubbly froth which is skimmed off the top of the flotation chamber for further processing.

Instrumentation used in mining operations range from materials-handling (e.g. weighfeeders for solid-ore conveyor systems, flow sensors for liquid-ore slurry piping and pump systems), explosive gas detectors, liquid and gas flow sensors for flotation processes, liquid level sensors, and special chemical analyzers. Motor controls, including variable-speed drive systems, are typically extensive in mining operations to regulate the transport of ore to the surface level and throughout the processing facility.

Aside from obvious physical hazards in a mine, a variety of chemical hazards exist due to exposure to the compounds in the extracted ore as well as chemicals used to enhance the separation processes. For the most part, there is little in the way of instrumentation inside of a mine, with most of the "action" happening at the surface level where separation takes place.

I have no personal experience working in or around mines, but I have heard it can be a challenging industry to automate. One of my professional heroes is a South African process engineer named Michael Brown who has worked as a process optimization consultant in a wide range of industries. Here is what he has to say[22] about mining:

> In the far distant past when I first started my own business we specialized in automating plants mainly on gold and platinum mines. Even inexperienced as I was in those days, I soon realized that the task was far from easy.
>
> Over the past few months I have been optimizing controls in mining applications including zinc and platinum mines. Once again I have come to the conclusion that controls operating in mining environments have to cater with some unique and specialized problems that are not encountered in many other industries. Amongst these are the facts that mining is a rough business with plant constructed very robustly in order to deal with extremely harsh operating conditions, and process control is a factor that is relatively far down on the list of design considerations when construction takes place. Products are also usually far from consistent. Typically ore varies considerably in physical properties

[22] This quotation comes from Michael Brown's article entitled *Control Loop Case History 60: Do Mines Have Particularly Bad Control Problems?* Reading this article, one is left to conclude that the only rational answer to this question is *yes*.

including consistency, size, density, and moisture content amongst many others. It is also extremely abrasive, which makes it hard to measure it, and severely limits one choice of suitable final control elements.

Measuring physical and chemical properties in mining is also often extremely difficult. Many parameters that require measuring present unique problems. To take a few examples, slurries are extremely abrasive, and there are only a few materials that can withstand such abrasion. One often has to measure levels of fluids that vary from abrasive and viscous, to liquids that are covered by a layer of foam that is almost as dense as the liquid itself. A couple of years ago I worked on the control of cyanide addition, where the sampling type cyanide concentration analyzer, had a scan (update) time of 17 minutes! The more modern versions have managed to reduce this time to about 9 minutes, which still introduces quite a long dead time for an important measurement being used in a feedback control system.

Mines tend to be located far from urban centers, and as such it is one of the industry sectors in which it is common for workers to live on-site for periods of time. Like offshore oil production, this often results in workers flying in to the job site for their duty and flying back to wherever home is when they are off work.

A potential development in mineral extraction is harvesting minerals dissolved in sea water and/or water taken from geothermal wells. This, in fact, is a potential source for *lithium* which has seen a significant increase in demand with the advent of lithium-ion batteries used in current-generation electric vehicles. A related industry is *metals recycling*, where various metals are extracted from waste and discarded products.

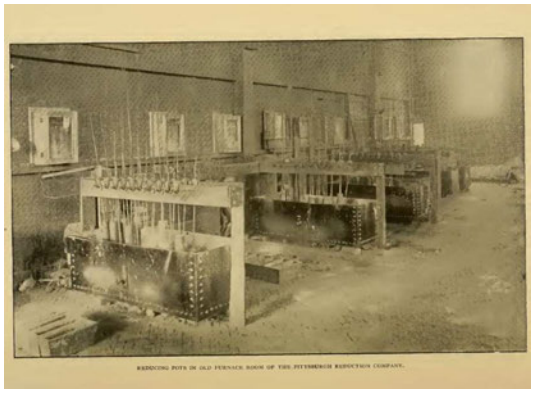
2.9 Smelters and Foundries

Closely related to mining are the smelting and foundry industries. *Smelting* is the process of refining mined ore into a particular base metal; a *foundry* is a facility for casting metal into various shapes.

The processes for smelting and casting metals vary substantially with the type of metal involved. This is particularly true of smelting, which is chemical in nature: most metals are found in nature as *oxide(s)* of the base element, which means these compounds must be chemically *reduced* to break the metal-oxygen molecular bonds and allow the metal to exist in its elemental form.

Aluminum smelters, for example, use an electrochemical process to reduce *alumina* (Al_2O_3 in powder form) into pure *aluminum* metal: extremely large[23] quantities of direct current (DC) are passed through an electrolyte solution containing dissolved Al_2O_3, forcing the three oxygen atoms (O_3) to dissociate from the two aluminum atoms (Al_2) in each alumina molecule, leaving the elemental aluminum free to coalesce into a molten pool which may be extracted and subsequently cast in a foundry.

Two photographs appear below showing aluminum smelting operations. The photo on the left is an early example of commercial aluminum production, taken in the year 1891 at the Pittsburgh Reduction Company. Each of the riveted iron boxes is a single reduction cell, or "pot" where the electrochemical reaction occurs. The vertical rods projecting out the top of each "pot" hold carbon *anodes* which form one-half of the electrolytic cell, the other half of the cell being the iron box (lined with carbon to protect the iron from the corrosive effects of the electrolyte). The right-hand photograph shows a modern aluminum smelter operated by Alcoa near the city of Reydarfjordur, Iceland (this public-domain image courtesy of Krator), the long buildings housing hundreds of industrial-scale reduction pots:



Electrochemical smelting requires extensive electrical instrumentation to control the flow of power from the power grid to the smelter, as well as monitors and controls on each of the reduction cells. This instrumentation is rather unique to this industry, and in some cases is custom-made for the smelter.

[23] The reduction cells shown in the 1891 Pittsburgh photograph measured 36 inches long by 18 inches wide, internally, and operated at a constant DC current of 5000 Amperes. Voltage drop was quite low, being only about 9 Volts for each of these cells. Modern reduction "pots" tend to operate at just over 4 Volts, at currents in the range of *hundreds of thousands of Amperes!*

The reduction of elemental iron from Fe_2O_3 is a much older example of reduction chemistry at work: in a modern steel mill the ore is fed into a *blast furnace* where carbon-rich *coke*[24] is burned under oxygen-poor conditions to product carbon monoxide gas. The carbon monoxide acts as a reducing agent for the Fe_2O_3, preferentially bonding with the oxygen atoms to form carbon dioxide (CO_2) gas and leaving molten iron (Fe) behind as a reaction product.

This photograph shows an old blast furnace formerly operated by US Steel along the Monongahela River in Homestead, Pennsylvania:

Such operations use extensive instrumentation to monitor and control the chemical reduction of ore into elemental metal and metal alloys. Pressure, temperature, level, flow, and analytical sensors abound, as well as control valves for throttling the flow of liquids and gases, and electric motor control systems for modulating the speed of rotating machines used to transport and process the ore and finished metal.

[24] Coke, in turn, is a product of coal combustion under low-oxygen conditions. Coal of high quality (called *metallurgical* coal) is fed into a series of ovens called *coke ovens* and partially burned to produce the coke which goes into the blast furnace.

Foundry operations involve the reheating, alloying, and/or casting of molten metal into various forms suitable for end-use or as feedstock for other metal-forming operations such as extrusion. A photograph of a steel casting in progress for the US Navy is shown here:

In comparison to smelting, foundry processes involve more physics and less chemistry. The major task at a foundry is to melt the metal at some specified temperature range, then pour that molten metal into molds where it solidifies. Obviously, temperature control is critically important here, and much of the instrumentation found in a foundry is related to the variable of temperature: temperature sensors, as well as control valves for throttling the flow of fuel and air to furnace burners, and in some foundries the control of large amounts of electric power to *electric furnaces* using electricity to melt metal[25].

The process of *alloying* metal consists of melting two or more substances together such that they thoroughly mix, prior to casting them into solid form. This, again, is more physics than chemistry, as the alloying elements generally do not *react* with the base metal to form new compounds. Proper proportioning of the alloy is critical to product quality, and so instrumentation is used to precisely measure batch weights and continuous flow rates to ensure the right mix.

Both smelter and foundry operations require massive amounts of energy[26], which means energy conservation techniques are key to profitability. This also means instrumentation and control plays a key role in maintaining the financial viability of any such facility. The energy must be measured, controlled, and recovered to the fullest practical extent in order to minimize waste and corresponding costs. The chemical reduction process by which pure metal is extracted from its oxide(s) often results in the release of carbon dioxide gas which means smelting operations can be significant sources of this greenhouse[27] gas.

[25] Two major categories of electric furnace are commonly used for foundry work: *arc furnaces* which use the heat of an electric arc through air or gas to melt metal, and *induction furnaces* where strong magnetic fields are used to "induce" electric currents within the metal sample to cause it to melt.

[26] With regard to smelting, this is an excellent example of the Law of Energy Conservation, which states that energy cannot be created or destroyed. Metal oxides such as Al_2O_3 and Fe_2O_3 are chemically stable compounds, their constituent atoms existing in rather low energy states. In order to separate the oxygen atoms from the metal atoms, one must invest energy to raise these atoms' energy levels to the point where they may exist independent of each other. Once upon a time, the metal and oxygen atoms *were* separated, but they released vast amounts of energy in the form of heat while combining to form these lower-energy oxide molecules (this oxidation being a slow version of combustion). In order to separate the atoms once more, that same amount of energy must be infused into the oxide molecule to un-do the bonds between the metal and oxygen atoms. There is no short-cut around this fundamental requirement for energy, because energy *must* be conserved.

[27] Carbon dioxide, methane, and some other gases are strong absorbers of infra-red light, which means they tend

Some metals are exceptionally difficult to smelt. Titanium is one such example, which explains its relatively high cost compared to other metals despite being very abundant in nature. The popular *Kroll* process used to reduce titanium from its oxide begins with a chemical reaction with chlorine gas to form $TiCl_4$, which is then reduced by exposure to hot magnesium metal to form elemental titanium. The titanium metal forms a porous mass called *sponge* which may then be sent to a foundry to be melted and cast into ingots of pure metal, or combined with other elements to form alloys[28] and then cast.

to act as gaseous solar energy collectors in the Earth's atmosphere, much like a greenhouse acts to trap heat from sunlight. Carbon dioxide gas emitted from fossil sources (e.g. coal used in iron production) represents a net increase in atmospheric CO_2, unlike organic emissions of CO_2 which form a net-zero *carbon cycle*. Emission of fossil-based carbon into the atmosphere is thereby a mechanism of climate change, and so these "greenhouse gases" are regarded as a form of pollution.

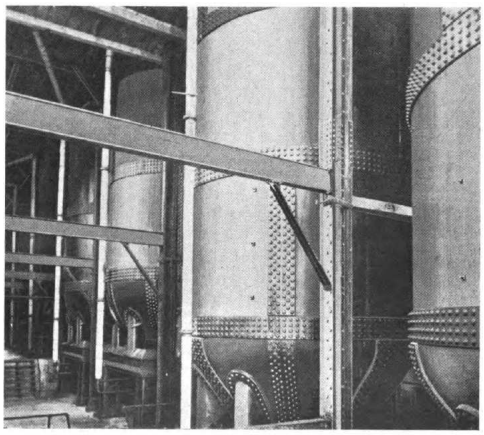
[28] An *alloy* is a solidified solution of two or more metals (and often non-metallic elements as well). Steel, for example, is an alloy (primarily) of iron and carbon. Bronze is an alloy of copper and tin.

2.10 Wood pulping and paper

The conversion of wood fiber into paper and other related products is another legacy industry that continues into the 21st century. Trees are a renewable resource, as well as being a significant *carbon sink*[29] in the Earth's carbon cycle.

Pulping virgin wood consists of using harsh chemicals (caustics and/or acids) to break down the natural adhesive known as *lignin* binding wood fibers together. The wood is generally cut into small chips, and those chips are then mixed with water and chemical reagents to be "cooked" in large digester vessels for long periods of time. The resulting mush looks something like watery oatmeal, consisting of water, wood fibers, and spent chemicals. The chemical compounds are extracted from the liquid pulp, and then the pulp is *de-watered* to leave the wood fibers which may be pressed and rolled into paper and other related products.

A photograph taken in the very early 1900's shows digester vessels at an International Paper pulp mill located near Niagara Falls. Note the riveted iron construction, typical of process vessels of that time period:



Digesters
The International Paper Company

A large portion of a pulp mill consists of chemical processing to recover as much of the valuable caustics and acids as possible for recycling back to the digesters, as well as after-treatments to the pulp (e.g. bleaching and coloring). This fact alone makes pulp mills rather complex and technically challenging places to work. Instrumentation is found practically *everywhere* in a pulp mill, from liquid level sensors to flow sensors to pressure sensors to temperature sensors to a wide range of liquid chemistry analyzers.

Some mills rely on other facilities to produce liquid pulp, and only process this pulp into paper and related products. Even so, the processes used to manufacture paper are quite complex and challenging. Large machines called *paper machines* use steam-heated belts and rollers to feed the

[29] Since we know carbon dioxide to be a "greenhouse gas" capturing infra-red radiation from the sun and therefore a contributing factor in the Earth's climate, it is important to have carbon (dioxide) sinks to help offset carbon (dioxide) emissions from the combustion of fossil fuels. Trees obtain their dry mass mostly from the absorption of carbon dioxide gas from the atmosphere and subsequent conversion into cellulose. Of course, a tree is only a "sink" for carbon so long as it never gets converted back into gaseous form, which means it must never be burnt. Wood products such as paper, therefore, sequester the trees' captured carbon so long as they are never used as fuel.

pulp into a linear process where more and more water is extracted from the pulp, and the paper layers are compressed in stages to achieve the desired thickness and quality. These paper machines use position sensors to detect where the paper sheet rides on the rollers, control systems taking this information to automatically adjust roller position to "steer" the paper on track.

This photograph[30] shows a modern paper mill operated by Metsa-Botnia in Kemi, Finland:

Pulp mills are almost as complex as oil refineries in terms of their instrumentation, but the paper industry is nowhere near as profitable an industry as petroleum, and so these mills tend to be less modern than your typical oil refinery. It is not uncommon to find instruments and control systems several decades old still in daily use at your average North American pulp mill.

An interesting point to mention about pulp and paper mills is their use of odd names to refer to equipment. While this tendency seems to exist in nearly all heavy industries, it seems in my experience to be most prevalent within the paper industry for some strange reason. Here you will find equipment commonly referred to by plant personnel by *brand name* rather than *function*. What is more, it is common to find equipment referred to by the brand name of the *previous model* it replaced years ago[31]. If and when you find yourself starting work in a place like this, don't be surprised if the people there give you strange looks for not knowing what all these terms mean, even if there is no logical reason why you should know any of these words yet. It is very difficult to objectively look past one's own culture, and this includes the culture of the workplace: if you've spent a decade or more working at a place where every machine has some nonsensical name attached to it, you will find that this nonsense becomes second nature to you, and may even reach the point where you consider with skepticism anyone who doesn't share this inner knowledge!

[30] Another public-domain photograph graciously provided by someone going by the internet name *Estormiz*.

[31] Funny story: I was once on a walking tour through a pulp mill, when the tour guide pointed to a large machine and referred to it as the *Derp*. After looking in vain for some kind of label or emblem on the machine with that title, I asked "what is a Derp?!" He chuckled and told me that this was the brand name of the *last* machine, and that the machine we were looking at was new enough that its brand name hadn't come into common use yet. Having worked in two different heavy industries (oil refining and metal smelting) where machines are more often referred to by their function, this struck me as odd and somewhat disorienting.

2.11 Lumber milling

Another use of trees is for structural material. Automation is key to being able to extract the greatest amount of economic value out of each and every tree harvested. The exact type of instrumentation varies with the specific application of the lumber mill. For a mill designed to cut lumber from virgin trees, the challenge is how to optimize each cut to take advantage of each tree's characteristics in proportion to the market value for each type of lumber. For a mill designed to convert reclaimed wood into other products, the challenge is how to identify defects in the incoming wood and maximally use whatever is left. For a mill designed to take lumber and convert it into specialty products (e.g. fenceposts, trusses) the challenge is to produce the final product with as little waste as possible.

Modern lumber mills utilize *machine vision* and other imagining-type sensors to inspect each log for its dimensions, growth ring structure, and placement of knots so that the best cuts may be made to turn the log into usable lumber.

A photograph showing a computer-controlled drilling machine placing holes in wooden power pole crossarms appears here:

Interestingly, at the mill where this photograph was taken there exists a steam boiler powered primarily by sawdust collected at various points in the mill. This would normally be a waste product, but this mill has found ways of using as a fuel for their main steam boiler, the steam being used in their kilns to drive moisture out of the incoming lumber prior to cutting and shaping into the final form.

Instrumentation at lumber-milling operations include motor controls for all the conveyors, saws, fans, drills, and other machines, steam boiler controls, temperature sensors for kilns, servo positioning systems for saws and drills, level sensors for sawdust storage, and a wide range of position sensors for detecting placement of the product as it goes through the cutting and milling processes. PLCs (Programmable Logic Controllers) are often the control system platform of choice for lumber mills.

2.12 Pharmaceuticals

The manufacture of medicinal drugs is a multi-billion dollar industry with new development happening at a fast pace. Modern drugs have proven to be life-saving for a large number of otherwise debilitating and/or terminal medical conditions, which makes their demand, and therefore[32] their

[32] Once again we see the Law of Supply and Demand at work!

price, very high[33].

Some drugs are purely synthetic, manufactured using processes completely alien to the natural world. Other drugs are manufactured by either mimicking or optimizing natural processes, with the general title used to describe these being *biopharmaceutical*. An example of biopharmaceutical production is the North American company Genentech which pioneered genetic manipulation of DNA to convert otherwise natural cells into microscopic protein-production factories, which are used to produce proteins which are the feedstocks of the final pharmaceutical product(s). By using feedstocks more compatible with the human body, drugs may be manufactured having (potentially) fewer undesired side-effects.

In either case, the manufacturing processes required for any pharmaceutical product is highly instrumented. Sensors measuring pressure, temperature, flow, liquid level, pH, electrical conductivity, and a host of other variables send signals to complex control systems which then regulate those variables using heaters, valves, pumps, and other final control devices.

This is a highly regulated industry, the major regulating body in the United States being the FDA (Food and Drug Administration). This regulation translates into an extremely regimented work plan for instrument technicians, with a veritable pile of forms to complete preceding and following most tasks. In this regard the pharmaceuticals industry is very much like the nuclear power industry. At times this strict adherence to protocol can be frustrating[34] to technicians, especially when they identify a problem that requires altering the instrumentation or the process in order to solve. Once a pharmaceutical process design has been certified, no design changes are allowed without a comprehensive (and very expensive) engineering evaluation to ensure that the proposed changes will not have any negative consequences.

[33] One could argue that poor health care policy and practices also contribute significantly to exorbitant drug pricing, but so long as there is freedom in the drug market the Law of Supply and Demand will have an undeniable effect.

[34] A former student of mine working in this industry once told me how he discovered a problem in a temperature measurement system causing a slight measurement error, but since the solution to this problem required wiring the sensor in a different fashion than it was originally certified for this process, he was not allowed to implement his fix. There was nothing novel to his solution, and in fact the way all the temperature sensors were wired was demonstrably incorrect (i.e. not as the manufacturer intended it to be wired) which meant there could not be any negative consequence to remedying it. Nevertheless, he was not allowed to alter the system at all, much to his chagrin.

The following photograph shows a small portion of a pharmaceutical manufacturing process. The stainless-steel vessel on the left-hand side of this photograph is called a *bioreactor* where cell cultures are grown in a carefully controlled environment (i.e. regulated temperature, pressure, pH, etc.). This particular photograph comes courtesy of Rick Lawless[35]:

The work environment inside a pharmaceutical plant is obviously quite clean. Much of the process equipment resembles a large laboratory, with gleaming stainless-steel vessels and piping everywhere. The dress code is typically casual, as the cleanliness of the process equipment directly translates into clean jobs for technicians.

Since the driving force behind pharmaceutical manufacturing is the continuous development of new and innovative drugs, the work culture tends to be one of innovation and creativity. The owners know that if their plant(s) do nothing but output the same product year after year, their profits will plummet after the patents expire and the drugs become available as generic to the consumer.

[35] This photograph is licensed under the Creative Commons Attribution-Only license version 3.0

2.13 Industrialized agriculture

The production of food is an ancient craft, and for reasons too obvious to state is an industry that *must* exist. As the world's population grows, the challenge of providing adequate food for everyone grows as well. As opposed to small-farm operations, industrialized agriculture is food production on a massive scale.

Applications of measurement and control within the agriculture industry include the following:

- Irrigation water flow measurement
- Irrigation machine automation
- Automated harvesting equipment
- Storage and preservation of harvested fruits, grains, milk
- Measurement of food commodities (custody transfer)
- Analysis of soil chemistry
- Manufacture of fertilizers, pesticides, and other food-related chemicals
- Manufacture of plant-based fuels (e.g. ethanol)
- Energy harvesting (e.g. manure digesters)

Of the items listed above, perhaps the most instrumentation-intensive is the manufacture of chemicals for food operations. This is industrial chemistry, on a scale comparable to any other form of chemical processing. The instrumentation found in such a facility is comparable to that of any other chemical plant: pressure, level, temperature, and flow sensors; chemical analyzers of many different types; control valves for throttling the flow of fluids; safety systems to automatically shut down the process in the event of emergencies.

The following photographs show two industrial-scale chemical operations based on plant feedstock. The left-hand photo shows some former students of mine doing contract instrumentation work at a fertilizer plant in Sergeant Bluff, Iowa. This particular facility manufactures granular urea and other nitrogen-based compounds used in the agriculture industry and other industries[36] as well. The right-hand photograph is a public-domain view of the Big River Resources, LLC ethanol plant in West Burlington, Iowa:

"Energy harvesting" as a sub-industry within agriculture deserves some elaboration. Food, ultimately, is a medium for energy storage, like *fuel* for an engine. Sunlight causes plants to grow, which are either harvested directly as fuel (or used as fuel for animals which indirectly serve as fuel) for omnivores such as ourselves. As food is processed, this captured solar energy inevitably spreads[37] to other forms. It is possible to capture some of this "spread" energy for practical use given the appropriate technologies. An example of captured energy is the burning of non-digestible "hulls" from food crops such as wheat. Ethanol production from corn (e.g. the Big River Resources ethanol facility shown above) and other plants is one more example of agriculture as a fuel source. Another example of captured energy is the bacterial digestion of animal manure to produce flammable gases (mostly methane, CH_4) which may be used to fuel engines to produce electricity.

[36] An example of a non-agricultural product of this particular plant is diesel exhaust after-treatment fluid, which is based on urea.

[37] This is an excellent example of the Second Law of Thermodynamics at work: any time energy is transferred, that energy takes on forms that are more diffuse than before. In a practical sense, this means the energy becomes *less usable*. An example would be the operation of a heat engine: energy contained in the fuel becomes converted into mechanical work (very useful) and heat rejected to the surrounding environment (not as useful). The Second Law is the reason it is impossible to design an engine that converts 100% of the fuel's energy into mechanical work.

Anaerobic digesters are process vessels designed to maintain a manure-water mixture at temperatures comparable to the body temperature of a mammal, allowing naturally present microbes to digest the organic compounds therein to release methane and other combustible gases. These gases may be compressed and used as fuel for internal-combustion vehicles, or to power stationary engines for the purpose of generating electricity. Photographs taken at an anaerobic digester located on a dairy farm show both applications – a compressed natural gas (CNG) dispensing station for fueling vehicles (left) and a stationary engine driving an electrical generator (right):

Not only do anaerobic digesters produce electricity from manure that would otherwise be considered waste, but the heat shed by the engine is used to provide space heating for the animals' shelter as well as the farmer's home! Additionally, the combustion products exiting the engine's exhaust are less environmentally damaging than the methane gas that would have been emitted (uncaptured) by the manure anyway, as methane is a potent greenhouse gas. An interesting footnote to this operation is the fact that it is used to process more than just cow manure: another feedstock to anaerobic digesters is commercial food waste such as fish guts. These food waste streams are even more energy-dense than manure, which is merely what is left over from the cow after it extracts energy from its food.

Instrumentation related to agricultural operations tends to be maintained by contracted labor, unless the operation in question is dense with automation as in the case of a fertilizer plant, in which case the company may maintain its own in-house technical staff. The anaerobic digester previously shown, for example, is maintained on contract by a company servicing many digesters within one county, simply because the maintenance needs of an operation such as this are few.

One future application of automation in the agriculture industry worth looking out for is robotic harvesting. Self-driving tractors are already a reality as of this writing (2017), but many fruits and vegetables are still harvested by unskilled manual labor. The advent of robotic harvesters not only promises an end to this toilsome labor but also the prospect of harvesting at all hours of the day (since robots do not require sleep) to capture produce as quickly as possible after ripening.

2.14 Food processing

Food processing is to agriculture as oil refining (downstream) is to oil production (upstream): simply the next logical step in the modern food chain. Every can of soup, box of cereal, loaf of bread, or other product found in a grocery store was processed somehow from raw ingredients, and in first-world nations most of this processing takes place on an industrial scale.

The following photograph shows the interior of a cereal manufacturing plant, with large ovens in the background:

Processes within a cereal plant range from mixing and baking to packaging and boxing. In fact, some of the most complex automation is found in the packaging and boxing machines which dispense measured quantities of food product into bags, then seal the bags inside of cardboard boxes which are folded and sealed by a robotic mechanism. Bagging and boxing machines are a maze of conveyors, robotic arms, batch-weighing scales, slide gates, heaters, and PLC (Programmable Logic Controller) controls.

Many other types of food-processing operations exist. One such operation is cheese production, an example shown here of a cheese plant in Idaho:

Food processing requiring fermentation or any other form of bacterial digestion relies heavily on instrumentation for the precise measurement and regulation of variables such as pressure, temperature, flow, pH, and reaction time in order to ensure the microbial action produces the desired result. Many common foods are processed in this way: cheese, yogurt, kefir, sauerkraut, bread, etc.

This next photograph shows the world's largest (as of 2017) yogurt plant located in Twin Falls, Idaho:

Sugar refining is another food processing operation, the following photographs showing such a facility in Twin Falls, Idaho:

The conversion of plants into granular sugar involves extensive separation and *drying* processes, all of them monitored and controlled using instrumentation. An interesting but hardly obvious facet of sugar production is the potential for *sugar dust explosions*. Sugar, being a chemical fuel, is extremely flammable in fine powder form. Dust concentrations in air must be monitored and controlled in order to avoid this hazard in a sugar production facility.

In addition to food production (upstream) and food processing (downstream) operations, intermediate food storage (midstream) also exists. One application of this is long-term fruit storage, a mid-way step between the seasonal harvesting of fruit and the direct marketing or processing of that fruit as food for consumers. In order to provide nutritious fruit to people at all times of the year, the fruit must somehow be stored in a way so that it does not substantially degrade. One way to do this for hard fruits such as apples is to store them in large buildings deprived of oxygen, in order to retard the natural process of oxidation and spoilage. This means erecting buildings that are air-tight, and equipping those buildings with machines that extract oxygen from the air within. Instrumentation, of course, is necessary for the safe and efficient operation of such storage buildings.

An interesting aspect of instrumentation work within the food processing industry is its diversity in terms of required skills and tasks. Profit margins within the food industry are quite thin, which means companies must do more with less in order to remain competitive. This translates to lower pay and a larger set of expectations for technical employees than more lucrative and specialized industries. It is not uncommon for "instrument technicians" in a food processing plant to be expected to do general mechanical and electrical work as well, and not specialize in just measurement and control.

2.15 Alcohol production

The industrial-scale production of alcohol resembles food processing in many ways, and often runs on similar feedstocks (grains in particular such as wheat and corn). Low-grade alcohols such as beer and wine are primarily *fermentation* processes where microbial yeast work to convert sugar molecules into alcohol molecules, releasing carbon dioxide gas as a byproduct. Higher-grade alcohols such as whiskey and gin require one more step in processing called *distillation* whereby the dilute alcohol taken from the fermentation process is purified by the removal of water. Processing of alcohol for use as an engine fuel requires substantial amounts of distillation.

This photograph shows a set of *mash tun* vessels at a beer brewery, where the grains are digested by yeast to produce alcohol:

The biological conversion of grains into alcohol happens only when the proper conditions of pressure and temperature are met, which is an application of measurement and control in this industry. Distillation is another process possible only when variables are precisely controlled: in this case, pressures, temperatures, levels, and flow rates.

Automation in the beer industry is an interesting example of cost versus benefit. In past years only large-scale beer breweries could justify the use of extensive automation, because only high-volume production would generate enough revenue to pay for the cost of the instrumentation and the skilled labor needed to maintain it. However, with the relatively recent popularity of specialized "craft" beers commanding higher prices, even small-scale breweries can afford to automate. Precise measurement and regulation of batch sizes, temperatures, fermentation time, and other variables is key to consistent production quality. Since the whole point of a "craft" beer is to make a uniquely flavored premium product, consistent product quality is necessary for people to pay more for a particular brand. Automation also saves quite a bit of money for beer brewers in its ability to control heat-transfer processes and to conserve water usage.

This same expansion of automation has not yet seemed to reach small-scale distilleries (i.e. craft liquors) as it has small-scale beer breweries, but it would not be surprising to see craft distilleries adopt a similar posture for the same reason: greater product consistency in order to command a higher price for a premium product. Distillation, which is what separates high-grade from low-grade alcohols, is a very energy-intensive process, and the energy savings resulting from tight control of distillation vessels is a well-known economic factor for other industries utilizing distillation (e.g. oil refining).

From a labor perspective, instrumentation is largely a contracted service for small-scale

operations. As important as automation is to these operations, there generally isn't enough in place requiring maintenance to justify the wages and benefits of an in-house technician.

2.16 Aerospace

Aerospace is a catch-all term for describing anything that flies, up to and including space travel. Career possibilities involving Instrumentation range from routine maintenance of aircraft measurement and control systems to research and development of new measurement and control systems. Routine aircraft work is heavily regulated in the United States by the FAA (Federal Aviation Administration), which means skilled jobs require specialized training and certifications[38]. Research and development of aerospace vehicles and systems, however, is more open to general instrumentation practitioners.

An interesting photograph is shown here, of the NASA rocket engine testing facility located in Stennis, Mississippi:

The large structure you see here houses a stationary rocket engine, physically secured so that it cannot leave the ground. As the engine is operated, various parameters are carefully measured (e.g. fuel flows, oxygen flows, thrust, temperatures, vibrations) to gauge the engine's performance.

[38] This comes under the general title of *avionics*, which is a combination of the words "aviation" and "electronics". One might think that this career would be an excellent match for military veterans trained on avionics systems for military aircraft, just as nuclear power plants are an excellent match for US Navy veterans trained in nuclear reactors, but there is a surprising disconnect in the avionics field. Military avionics systems tend to be state-of-the-art, with lots of "black boxes", standardization, and component self-diagnostics. Commercial (civilian) avionics, by contrast, often consists of a mix of new and legacy components requiring a skilled avionics technician to function harmoniously. I spoke at length with one commercial avionics operations manager who was outright frustrated with the inability of military-trained avionics technicians to manage the mixed systems common to commercial aircraft.

2.17 Semiconductor processing

Semiconductors are a class of material comprising the heart of all modern electronic technologies and devices. Unlike conductors which always permit the flow of electricity, and insulators which always prohibit the flow of electricity, semiconductors exhibit the unique property of being able to switch between conductive and insulating states. This means semiconductor-based devices are able to *control* the flow of electricity through them.

The dominant base material for modern semiconductors is *silicon*, one of the more abundant elements in the Earth's crust. However, in order to be useful as an electronic semiconductor, silicon must be refined to a state of exceptional purity – far beyond that found in nature. Once silicon has been thus refined and drawn into solid ingots, the ingots are then sliced into thin *wafers*. After this step, the wafers are sent to factories to be processed into usable electronic devices such as transistors, diodes, solar cells, and integrated circuits.

Manufacturing facilities for producing purified silicon resemble any industrial chemical operation, with large reactor vessels, distillation columns, cooling towers, pumps, compressors, and other chemical processing equipment. Manufacturing facilities built to take pure silicon and make circuit components from it are quite different: the processing equipment being much smaller, and located inside of *clean rooms*[39] where the air is super-filtered to eliminate particles of dust and pollen which would ruin the silicon wafers. Extensive instrumentation and controls are used to maintain a regulated environment for the machinery in these clean rooms to operate, while other instrumentation and controls provide utilities such as ultra-pure water, high vacuum, and gases used in the manufacturing process.

The following photograph shows a typical clean room work environment, where workers must wear white suits to prevent hairs and skin particles from falling into the clean room. This particular photograph comes courtesy of Steve Jurvetson[40]:

[39] The common industry term for this type of facility is a *fab*, which is short for *fabrication*. It's essentially an ultra-clean assembly line where silicon wafers are formed into circuit components by a process called *lithography*.

[40] This photograph is licensed under the Creative Commons Attribution-Only license version 2.0

2.18 General manufacturing

In contrast to *processing* industries that output continuous streams such as electricity, fluids, powders, or food, *manufacturing* industries focus on the design and assembly of *special-purpose items*.

A very important manufacturing concept in the United States is that of *lean production*. The general concept here is that the operation should be as lean (as opposed to fat) as possible, minimizing inventory, "bottlenecks" (disproportionate limitations), and waste of every kind. Quality monitoring and control is extremely important to all "lean" manufacturing methods, as well as team-building to foster an efficient and enjoyable work culture.

A number of different "lean" programs exist, including *Six Sigma* which is popular in the United States. Certifications exist for many of these lean manufacturing programs.

Shown here is a photograph of one of my former students, David Williams, while working at Tesla Motors in California. In this photo he is standing near a Fanuc robot that he programmed to insert bearings into drive motors for one of Tesla's models of electric car:

Manufacturing environments tend to heavily utilize Programmable Logic Controllers (PLCs) as their control system of choice. PLCs are easily re-programmed when changes need to be made on a production line, and are relatively inexpensive compared to some other types of control systems such as SCADA (Supervisory Control And Data Acquisition) and DCS (Distributed Control System).

The sensor instrumentation used in manufacturing environments tends to lean more toward *discrete* (on/off) than *continuous*. Position sensors used to detect placement of objects on an assembly line, for example, provide simple go/no-go indication of that object's proximity, as opposed to a continuous sensor which would measure precisely how far away the object is. The discrete nature of most manufacturing-based sensors is another reason why PLCs are generally the control system of choice in these environments: PLCs excel at managing large amounts of discrete-sensor data.

Another type of control system unique to manufacturing is Closed Numerical Control, or *CNC*, initially developed for the machine tool industry. CNC control systems are designed primarily for high-accuracy speed and position control, of the type necessary for machine tools such as lathes

and mills. Within every CNC machine there exists a host of sensors for monitoring tool position, rotational speed, axis position, coolant flow, clamping pressure, and other variables necessary for fast and safe machining. CNC computers are specialty control systems designed to directly input this sensor information, as well as receive commands from either a human machinist or another computer directing it to cut, grind, drill, turn, and otherwise manipulate the piece being machined. Modern CNC systems may also integrate vision sensors in addition to speed and position sensors to detect product flaws.

CNC machine maintenance is its own specialty within Instrumentation. The career is highly mechanical in nature, since the machines in question are built for very precise positioning and accurate motion and therefore require extensive alignment and routine replacement of wearing parts. The sensors used in CNC machine tools are also highly precise, and the CNC control computer is essentially a motion-control system designed to follow instructions input by either a human machinist or a CAD/CAM (Computer-Aided Design / Computer-Aided Manufacturing) system which compiles mechanical diagrams into CNC code.

An interesting type of process developed specifically for the manufacturing industries and rapidly gaining popularity (even among hobbyists!) is called *rapid prototyping*. These are essentially three-dimensional printing machines able to create objects based on computer-based models. Most 3D-printers at this time use plastic as the prototype medium, but metal-powder printers are also becoming available. Initially developed as a way to quickly manufacture prototype objects for ergonomic testing, this technology is becoming robust enough in some cases to manufacture final products. When used as such, it is an example of *additive manufacturing*, where the item produced is created by adding layers of material (as opposed to the more traditional *subtractive* manufacturing where material is removed in order to form a product).

2.19 Standards laboratories

Metrology is the science of precise measurement, and *standards laboratories* are places housing equipment designed to serve as references for many types of measurement. A range of technical skills are necessary to maintain and utilize these metrological standards, from scientists to technicians.

The following photographs show a rack of voltage standards used to compare against voltage-sensing instruments brought in to the standards laboratory for routine calibration (left), and a Josephson Junction primary standard for electrical voltage (right):

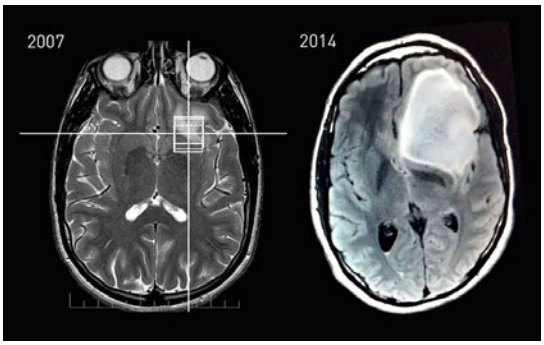
Virtually all industries require accurate measurement, and standards laboratories are the places where calibration equipment gets checked. This process of comparing calibrations against standards of higher quality, all the way up to primary standards laboratories, is called *traceability*. Like pedigree for animal breeding, traceability documents the integrity of the "calibration chain" extending back to those primary standards.

The instruments used within standards laboratories are strange beasts compared to industrial field instruments. Primary standards are especially so, devices such as the Josephson Junction array shown in the previous photograph requiring an on-staff engineer and/or scientist to maintain. A great many metrological instruments are electrical in nature, and the techniques used to connect such instruments together to measure electrical quantities such as voltage, current, resistance, capacitance, inductance, and power are far from trivial. What might ordinarily be considered "negligible" becomes of paramount importance in the metrological world: *noise* voltages, *leakage* currents, *stray* electric and magnetic fields, *background* radiation, and the like all conspire to corrupt accuracy. When one is attempting to achieve measurement uncertainties in the *parts per million* or even *parts per billion* range, these "negligible" effects cannot be ignored. Connection techniques such as the *Kelvin 4-wire method*, rooms shielded from external electric fields by copper mesh paneling, and other mitigation measures are commonplace within metrology laboratories.

2.20 Medical instrumentation

Modern health care is extremely dependent on measurement. From blood pressure monitors to EKG and EEG monitors to scanning machines such as CAT, PET, and MRI, data obtained by precise medical instruments is indispensable to fast and accurate diagnosis of conditions. These devices and systems require periodic calibration and maintenance, like any other machine, and technicians trained in their specifics are hired to do this work.

An example of an MRI (Magnetic Resonance Imager) machine's diagnostic capability is seen in the left-hand pair of images from the same patient over a 7 year timespan, showing the presence of a tumor called an astrocytoma in the later image. The right-hand photograph shows the exterior of such a machine, where the patient lies within the center aperture of the machine surrounded by powerful electromagnets generating the intense magnetic field necessary to produce such images:



Much of medical instrumentation service is done on a contract basis rather than each hospital or imaging center maintaining its own in-house technicians. Also, the certifications required for working on this equipment are specialized and often manufacturer-dependent. It is quite common for this work to be done by the manufacturer of the imaging equipment[41] by their own technicians trained to service that specific equipment (e.g. an MRI imaging machine manufactured by Siemens being serviced exclusively by Siemens-employed field technicians). However, in general the principles applied in medical instrumentation are remarkably similar to those used in industrial instrumentation, and so any competent industrial instrument technician would find it relatively easy to adapt to this field.

[41] Modern medical imaging equipment such as MRI (Magnetic Resonance Imaging) tends to be *extremely* expensive, and so it makes sense to trust the ongoing maintenance of such equipment to factory field technicians, so that any malfunctions may be covered by the manufacturer's warranty.

2.21 Systems integration

When industrial facilities need new control systems installed or upgraded, they often contract the control system selection, design, programming, documentation, and installation to an outside company called a *systems integrator*. The systems integrator accepts work on a contract basis, then handles all technical details of that work until the job is complete.

The bulk of work performed by a systems integrator may be divided into two categories: *design* and *construction*. Design consists of assessing the client's control system needs, selecting available control system components from various manufacturers, and then configuring and programming those components in order to meet the client's requirements. A challenging aspect of this design work is determining what instrumentation and controls currently exists at the client's site, because often these systems have been modified over many years by maintenance personnel with little or no ongoing documentation. Construction consists of installing components into electrical enclosures (called "panels"), connecting wires between those components, and certifying that the construction of those panels meet applicable national codes. Following this "panel shop" work, the equipment must then be installed on the plant site and commissioned to ensure its proper function. A challenging aspect of this construction work is placing the new equipment on-line with minimal interruption to the client's physical processes.

2.22 Systems engineering

When a manufacturer or processor needs to upgrade their physical plant (not just the control systems), the work required to do so often exceeds the capabilities of both that organization's staffing and that of a systems integration firm. *Engineering* firms exist to fulfill this larger need by providing design, construction, and/or documentation services on contract. Instrument technicians may find work within this industry sector in two very different forms: hands-on work during the construction process, and document design work during the planning and final checking process.

Hands-on instrument technician work hardly requires elaboration at this point: the technician installs, calibrates, configures, and tests new instruments as part of the construction process.

Instrument *design* work consists of creating and/or maintaining documentation for industrial control systems. The title *instrument designer* is somewhat misleading: these specialists do not actually design *instruments*, but rather draft and edit the *documentation* representing working instrumentation systems. This line of work is certainly not for everyone. Most of the time spent on the job by an instrument designer will be in an office cubicle, working with CAD (Computer Aided Design) software such as `AutoCAD` and instrument database software such as `InTools`.

The work of a process engineering firm occurs in phases, the following being a typical sequence in the life of a major project:

1. Client contacts the engineering firm and requests a project. Often the client will contact *multiple* engineering firms requesting each of them submit a proposal (RFP = Request For Proposal) describing how they would engineer a solution to the client's problem.
2. Engineers at the firm develop a conceptual design with a $\pm$ 50% cost estimate.
3. P&ID (Process and Instrumentation Diagram) documentation drafted, showing all piping, vessels, equipment, and control strategies which will be used to fulfill the desired process function(s). Cost estimate within $\pm$ 10% of final cost.
4. Instrument loop diagrams, schematic diagrams, configuration sheets, and other detailed documents describing system instrumentation are developed by instrument designers.
5. Construction begins, with the engineering firm providing technical support during this phase. This support may or may not include on-site technical personnel to assist with problem-solving.
6. As-Built verification once construction is complete, ensuring all documentation matches what has been built.
7. Other services provided after the project is operational include technical writing (e.g. operations manuals, procedures), training for operations and maintenance personnel, service contracts, etc.

2.23 Contract technical work

This category isn't really an *industry* so much as it is a *mode* of employment. Many industries cannot justify the continual employment of their own instrumentation specialists, and so they will hire instrument technicians, fitters, metrologists, and even engineers on a contract basis to perform work for some limited time. In some cases, contract employees supplement a small contingent of in-house employees, allowing the company to reduce or expand its labor pool on demand as needs arise from major expansion or maintenance projects.

One such application is found in the electrical power industry, where generating stations are taken off-line for routine maintenance work every few years. These *outages* are opportunities to perform work that cannot be done when the station is running. For thermal power plants, this means tasks such as cleaning and inspecting boilers. For nuclear plants this means refueling the reactor. For hydroelectric plants this means inspecting and repairing cavitation damage to the turbines. While the plant is fully shut down, certain instrument maintenance tasks such as transmitter calibration, control system software upgrades, and safety system testing may be performed without the usual regard for unnecessarily "tripping" the unit off-line.

Another application of large-scale contract instrumentation work is in the oil refining and chemical processing industries. Both of these industries utilize catalytic chemical reactors for efficient processing, and the catalyst requires periodic replacement. This, again, requires complete shut-down of the operation (usually every few years), which affords good opportunity to perform other maintenance and upgrade work that would otherwise be risky or impossible to perform when the plant is running. These shut-down events are called *turnarounds*.

An interesting dynamic within the United States petroleum industry is that new refinery construction is rare. The number of operating oil refineries in the US has been steadily declining, while overall production capacity has been steadily increasing. Simply put, the advantages of "economy of scale" drive this trend, as oil companies find they can be more profitable running a few large refineries than many small refineries. Refinery expansion means *construction* of new units, upgrades to existing units, and a large amount of contracted labor to do it all. Ever-increasing regulatory pressure from the US government force oil refineries to modify their processes to consume less energy, emit fewer pollutants, and produce better products. This also requires ongoing project work, which requires bursts of construction activity made possible through contracted technical labor.

On the smaller end of the industrial scale, there exist many operations with just a few instruments requiring periodic attention. A craft beer brewery, or a water treatment facility for a small town, to give just two examples, cannot financially justify maintaining their own staff of instrument technicians to calibrate and troubleshoot a mere handful of controls. Thus, contracted instrument technicians are used to fulfill this need.

Working as a contract instrument technician is in some ways similar to running your own business. The work necessarily involves greater financial risk than working a steady 40-hour-per-week "in-house" job, because you never know from one month to the next where or even if you will be working. Personal reputation also matters much more as a contract employee for the simple reason that you are easier to fire than an "in-house" employee filling a permanent position. The contract instrument

world seems to have its own communication network among employers, whereby reputation travels far and fast: whether you do a good job or a poor job, *your name will become known*. For this reason, many contract instrument technicians find their next job by word of mouth: talking with co-workers, receiving phone calls and emails from interested contract companies, etc.

An important fact to mention about contract work is that it tends to pay very, very well. This is especially true with the job in question is within a lucrative industry such as electric power generation or oil refining. Not only is the hourly wage substantially greater than what an "in-house" technician earns for the same work, but an additional bonus called a *per diem* is usually included to help the employee pay for daily expenses such as food, lodging, and fuel. These *per diem* bonuses are often generous, and may be banked through judicious control of daily expenses.

Contract work is also more welcoming of inexperienced technicians than "in-house" positions. Again, the reason for this is the fact that contracted employees less expensive to take on and are easier to fire if they turn out to be unfit for the job. This makes contract work very attractive for fresh graduates of technical schools: it's a great way to gain a lot of experience quickly, see many different industries, and pay off student loans. It is also worth noting that many large companies view their contract technicians as potential "in-house" employees, which means you may find yourself in a very good position to secure a more permanent job if you spend a few years doing contract work.

2.24 Technical Sales and Service

While certainly not a good fit for every personality, *instrument sales* is an under-explored career path for many instrument technicians and engineers. This involves working either directly for an instrument manufacturer, or working for a vendor representing one or more manufacturers. Unlike consumer sales jobs, technical sales deals with a highly informed and critical client base. The products being sold are essential to the safe and efficient operation of multi-million dollar processes, and so the technical salesperson *must* be responsive to the client's needs.

Technical sales professionals are roughly divided into two categories: *inside* sales and *outside* sales. An "inside" salesperson helps customers select technical products while working from an office, while an "outside" salesperson actually visits the field sites where the products in question are installed and serviced.

A large part of a successful technical salesperson's job is *educating* the client on specific options and capabilities of the product being sold. The client may have a very good understanding of what the instrument *needs* to do, but the salesperson is the expert on what their instrument *will* do. Outside salespeople often spend time at their clients' sites giving technical presentations, answering questions, diagnosing faults on installed products, etc.

Manufacturers and vendors often struggle to find good employees for this career. What is necessary to succeed in this business is an outgoing personality combined with strong technical expertise, the ability to continually learn new technologies, and the integrity to be honest with the client at all times. Salespeople accustomed to marketing consumer products (e.g. automobiles, furniture) may fail in this regard, where the client's match with the product is often subjective. In the very objective world of Instrumentation, *the only way the client is going to be happy is if the product functions as it should.*

Closely related to outside sales is *field service*, which means you are a technician (or engineer) tasked with repairing or upgrading a product on the customer's site. This may occur because the product in question has been purchased with a factory service agreement, in which case service must be done by factory representatives and not the client. It may also happen if a client orders and installs an instrument, then discovers it fails prematurely or otherwise performs at an unexpectedly low level: it may cost less to pay for a factory-authorized technician to troubleshoot the problem than it would to dedicate others less familiar with the product to that same task.

Compensation in the world of sales is almost always based to some extend on commission: a percentage of the total sales volume. This is a natural incentive for the salesperson to sell more, which is precisely what every manufacturer prefers. However, there is usually a certain portion of a technical salesperson's income that is fixed and not tied to the number of items or total value of items sold. This ratio between fixed and commission varies with the employer.

Manufacturers and vendors selling *safety* technologies often enjoy a more stable revenue stream than those selling base-level measurement and control instruments, because many safety standards are mandated by state and/or federal law, and as a result the purchasing of consumables and upgrades for those safety-related products tend to happen irrespective of the general economy.

Chapter 3

What makes an employee valuable?

The longer I live, the more respect I gain for the field of Economics. Economics is not just the study of money, but it is the study of risk and reward, of cost and benefit, of consequences both intentional and unintentional. Underpinning most economic theories is the belief that people generally act in their own self-interest, and that the actions of many people individually following their own selfish interests constitute complex economies. This crass yet embarrassingly accurate view of human nature helps explain a great many things, not the least of which being those qualities which will secure a career for you in the field of industrial instrumentation.

It is essential to understand that every employer-employee relationship is a *mutual contract*. The employer offers financial compensation and benefits in exchange for the employee offering their knowledge, skill, and labor. Like all commodities, expertise is valued in proportion to its demand and inversely to its supply: this is the *Law of Supply and Demand*. That is to say, the only reason an employer pays a premium wage is for an employee offering something that is both necessary for the enterprise *and* rare to find. This is the zone you want to be in to maximize your earning potential: whatever is in high demand and low supply.

The question of what makes an instrument technician valuable to any employer is therefore a matter of leveraging supply and demand. Simply put, you want to create for yourself a set of skills and professional habits that are both necessary and uncommon. It is here we find another important principle of economics helpful to our understanding of value in the labor market: *human capital*. Simply put, human capital is the sum total of all knowledge, skills, abilities, habits, and traits enabling a person to optimize their own quality of life. The value of human capital varies with environment: the knowledge, skills, abilities, etc. which make a person able to survive in the wilderness with nothing more than the clothes on their back, for example, varies greatly from the set of knowledge, skills, abilities, etc. that enable success as a corporate accountant. Within any particular career there will be a particular set of knowledge, skills, abilities, etc. considered valuable and worthy of compensation, because the nature of compensation for work is that the employer pays for the privilege of enjoying the employee's human capital.

Human capital, more than any other reason, explains why some employees get compensated more than others. To be sure, some people find themselves in jobs that either pay well above or well below their own human capital by accident, but on the average this is not how compensation works in a free-market economy. Where workers are free to apply for and accept other jobs, people tend

to move where they will be best compensated: an under-paid employee will find a better job, and an over-paid employee will eventually get replaced by someone better qualified. When companies suddenly go out of business and lay off all of their employees, it is striking to note how closely those employees' new jobs mirror their old both in scope and compensation. If compensation were merely a function of luck, you would see most peoples' circumstances change after a layoff. Instead, you see most of the highly-paid people finding new high-pay jobs, and most of the lowly-paid people finding new low-pay jobs. What makes this difference is the human capital carried by each person.

While certain aspects of human capital can be career-specific, others are quite general. Inattentiveness, for example, is a deficit no matter what one's station is in life: an inattentive wilderness adventurer is less likely to survive just as an inattentive accountant is less likely to do their job well. Intelligence, as another example, is a trait positively associated with success no matter the environment. It lies within your own best interest to identify which aspects of human capital are most associated with success in your environment, specifically within the career of Instrumentation, and work to improve those aspects you can.

Here are some specific aspects of human capital considered valuable in the field of industrial Instrumentation, listed in no particular order:

- **Integrity** – being honest and forthright in your work, so that people will trust you to do your job. Trust is the lifeblood of any relationship, and this includes business relationships.

- **Curiosity** – wanting to know *how* and *why* things work is key to solving tough technical problems and staying abreast of technological developments. This is also hard to find, as most peoples' interests are captured by baser matters.

- **Attention to Detail** – little things matter in this career, from typographical errors on diagrams to skipped steps in procedures. Lazy people as a rule don't pay attention to detail. If you haven't noticed, there are a *lot* of lazy people in this world.

- **Conscientiousness** – making sure the job is done correctly, every time. This requires a certain degree of humility in recognizing one's own capacity to make mistakes, and habitually double-checking your own work as a direct consequence of that recognition.

- **Persistence** – not giving up when faced with challenging circumstances.

- **Resourcefulness** – being able to make good use of whatever resources one happens to have to get the job done. The opposite of this is someone who cannot function unless the optimum environment and tools are given to them by someone else.

- **Communication** – the ability to express complex ideas in clear language. For those raised on a diet of internet social media, this means writing and speaking in complete sentences rather than the crude blend of juvenile slang and stenographer's shorthand that passes for text messages and online comments. For everyone, it means checking assumptions and alternate viewpoints so that when you do write or speak it will be easily understood by others.

- **Initiative** – not needing to be told what to do, but self-starting on necessary tasks. The value of this from an employer's perspective should be obvious: the more self-directed an employee is, the less work it is to oversee them.

Please note how many of these attributes apply to careers other than Instrumentation, but are valuable in any career where there is substantial responsibility. Take this as an important lesson: being a valued Instrumentation practitioner means first and foremost being the kind of person *you* would want to hire to get *any* technical job done.

As an instructor at a technical college, I enjoy a privileged view on the aspects of human capital valued by employers, and that is because I am in constant contact with employers seeking qualified people to work for them as technicians. I have witnessed interviews conducted by employers visiting the college, served as a reference for graduates applying for work in this field, received feedback (both good and bad) from both graduates and from employers, and served on numerous committees where employer recommendations were taken to either build new technical education programs or improve existing programs.

When employers contact me to inquire about a graduate they are considering for hire, the first and foremost attribute they ask me about any former student is that person's *attendance record*. At first this may seem odd, as class attendance has nothing to do with technical knowledge or skill. However, it is a crude indicator of *work ethic*. Someone who is habitually late or absent is most likely not a motivated individual, and will therefore make a poor employee regardless of knowledge or skill. Simply put, good attendance is a remarkably valid indicator of some of the most important aspects of human capital for this field.

It surprises many students to hear that employers are generally disinterested in grades, but are much more interested in details of their performance such as resourcefulness, interpersonal communication, teamwork, and curiosity. Employers understand that many factors unrelated to human capital may affect course grades, and that this is especially true for adult students balancing demands of family, part-time career, and other obligations common to adult life.

My job as an instructor also gives me a privileged view on the various expressions of human capital in student performance, because my position allows me to correlate student performance with career performance: after closely observing students for the better part of a calendar year, I get to see who does better in their new careers. These observations have taught me to pay close attention to the following "red flag" indicators when exhibited by students:

- **Failure to heed schedules** – when a student fails to note what date a class begins on, when the class meets, and where on campus it is located, it almost always indicates future problems securing employment. When all this information is clearly shown on the student's class schedule, such failures point to a lack of attentiveness and self-discipline which dramatically reduce one's human capital in this field.

- **Inability to work independently** – coursework requiring students to complete certain tasks entirely on their own are excellent indicators of readiness for employment in this field. The task itself need not be complex, just something with a firm deadline that will not be shared amongst classmates. Examples include independently gathering tools to meet a tool list requirement for a course, writing a résumé, etc.

- **Excuse-making** – people who habitually present excuses for their lack of accomplishment are people who do not accept responsibility for the final outcome of their actions. They believe trying is all that counts, which will come as a rude awakening when they *try* to find a job.

- **Absences without contact** – all students, adult students especially, will need to miss class from time to time for reasons of illness, important appointments, emergencies, etc. The mere fact of absence itself is not necessarily a problem, but I always make clear to students the importance of contacting their instructor as well as their teammates by the start of class if they know they will be absent. The practical reason for this is so that their team can shift their work plan based on an estimate of when their absent teammate will return. The need for contact in case of absence has proven to be a reliable indicator of a student's sense of personal responsibility: responsible students have no problem making prior contact, irresponsible students typically make contact late or not at all.

- **Procrastination** – this is when a student knows when work is due, but waits until the last minute to complete that work. This is an expression of poor judgment, as any human being old enough to attend college is old enough to know expect the unexpected: unforeseen events *will* occur to delay your progress. Waiting until the last minute invites failure, because procrastination naively assumes the unexpected will never occur.

- **Addictive behavior** – it is the nature of an addiction to control a person's behavior, to override rational judgment, to hamper their ability to function in a healthy way, all in a single-minded attempt to satisfy the craving. Substance abuse is just one form of addictive behavior, but there are many others: people may be addicted to social media, computer gaming, gambling, eating, melodramatic relationships, frivolous spending, etc. Addictions severely degrade human capital because of their all-consuming nature.

- **Emotional outbursts to classmates** – sadly, I have witnessed this behavior in students of *all* ages, and it never bodes well.

- **"But I'm a different person outside of school!"** – when a student exhibits poor habits, such as failing to arrive to class on time, failing to take initiative, etc. and when confronted they claim this sort of problem *only occurs in school* but never in any other context, it is a *guaranteed* sign of future trouble. This person not only has a deficit of human capital, but it unwilling to admit as much and therefore will do nothing to remedy their deficit.

- **Entitlement attitude** – this can take many forms, but whenever a student declares they *deserve* something, it is a sure sign of trouble. At the risk of offending readers, let me make the following point crystal-clear: *anything you enjoy in life is either received as a gift, or it has been secured by someone's hard work – absolutely nothing is deserved.* Even things as precious to modern civilization as human rights and the rule of law aren't really entitlements at all: they are values for which *some* people are willing to fight to maintain, and *will* be lost if not enough people keep fighting for them. Entitlement attitudes are a burden to everyone else, because the self-entitled person inevitably demands more than they offer. Nobody wants to work with such people, and most supervisors are particularly skilled at detecting this undesirable trait because they have had to suffer its consequences on the job. I have witnessed interviewers repeatedly (and accurately) detect entitlement attitudes in student applicants, and so I can say with confidence that this trait is responsible for a large number of failed attempts to get hired.

- **Failure to activate email account** – every one of my students is given an email account by the college, which I use to send job announcements, tour information, and other important

> announcements. What I find shocking is just how good of an indicator of future trouble email activation is. The task itself is trivial, and the college even offers free technical assistance to students if they encounter difficulty, but I have found that every single one of my students who ever failed to activate their email accounts when asked have also lagged in securing employment. Every. Single. One.

When I witness graduates who struggle to succeed in their chosen careers, it is rarely due to a lack of intelligence, knowledge, or skill. Career trouble usually stems from a deficit in the "softer", non-technical elements of human capital. Anyone choosing Instrumentation as their career needs to bear this in mind, and begin working to improve their "soft skills" wherever possible. A good educational program for this field directs students' attention to *all* aspects of human capital necessary for career success, but ultimately things such as poor habits cannot be undone without the individual's full consent and focused effort.

Employer surveys are useful sources of information for identifying specific aspects of human capital valued in jobs. Consider the results of the January 2013 Washington State Workforce Training and Education Coordinating Board's survey gathering input from over 2800 employers in the state of Washington spanning a range of industries. One of the questions asked by this survey polled employers for areas of difficulty they had experienced with new employees (i.e. people freshly graduated from school):

Knowledge/Skill Area	**Percentage experiencing difficulty**
Solve problems and make decisions	50%
Take responsibility for learning	43%
Listen actively	40%
Observe critically	38%
Read with understanding	32%
Use math to solve problems and communicate	31%

This data tracks well with national surveys, including the Manufacturing Institute and Deloitte Development LLC's 2011 survey polling 1123 employer respondents with a very similar question (*"What are the most serious skill deficiencies in your current employees?"*):

Knowledge/Skill Area	**Percentage experiencing difficulty**
Inadequate problem-solving skills	52%
Lack of basic technical training	43%
Inadequate "soft skills" (attendance, work ethic)	40%
Inadequate computer skills	36%
Inadequate math skills	30%
Inadequate reading/writing/communication skills	29%

Do you see any patterns here? Obviously, general problem-solving is a deficit for *approximately one-half of all new employees*. Communication (listening, reading, writing) is also problematic, as is mathematics. Lest anyone think that the 36% dissatisfaction rate for computer skills is generational, believe me when I tell you they aren't referring to social media or computer games here: the computer skills I've seen employers demand are things such as *spreadsheet use*, *word processing*, *design software* such as CAD, as well as general *operating system* use (e.g. archiving files, installing new software applications, uninstalling applications, sharing data on network drives, copying and deleting files). A majority of the incoming students I encounter lack these skills regardless of their familiarity with entertainment-based software such as social media applications and video games.

Interestingly, the 2013 Washington state board survey also provides a sobering statistic regarding on-the-job training. One of the questions on this survey read, "Did you firm provide at least 4 hours of on-the-job training under a written plan for any employees in the last 12 months?" The responses were only 31% yes and 69% no. You will find that this is fairly typical within industry: technical training opportunities are often few and far between, with the responsibility for ongoing professional development usually left to the employees.

Training is expensive, not only in its direct costs but also in the need to pull workers away from their regular duties to give them time to train. A progressive approach to training sees this expense as an investment, but this is only true if the training is relevant and effective. Far too often the topics of training are limited to those mandated by regulation (e.g. safety, legal, environmental compliance) with few controls to ensure each and every participant gains real knowledge.

Even when an employer has a robust training program for their employees, the topics of training will be limited to whatever is specifically needed for that employer. The reason for this is obvious: if the employer views training as an investment, then it is in their own interest to get the best return on that investment. This means training on topics that will help the employer first and foremost, and avoiding topics that might make employees more valuable elsewhere (lest they leave and go to work for someone else). For this reason, one should never look toward employer-based training as a sufficient way to advance one's own *career*, but merely to improve skill for the *job at hand*. In order to build your own human capital as broadly as possible, so that you will have employment options beyond your current employer, you will need to educate yourself in ways other than the training offered to you on the job.

The bitter truth about training for instrument technicians is that *you and you alone are responsible for driving your own professional development*. Your employer will provide you with some training, but it will not be sufficient for the development of a full career in this field.

Chapter 4

Locating Employment

Identifying employment opportunities within the field of Instrumentation is more complicated than it should be. Practically every modern industry relies heavily on instrumentation and control for safe and efficient operation, yet the career itself is largely unknown to the general public, and misunderstood even among some industry professionals. Many factors contribute to this problem, including:

- The career itself is largely out of view of the general public. Few people even realize it exists.
- The technical field of Instrumentation in the United States is wildly diverse, with few standardized licenses, certifications, etc. across the range of industries served. It is almost impossible to accurately describe the work of an "instrument technician" across all industries, and in many cases the job isn't even listed under that title.
- The work of an instrument technician tends to be much more abstract than that of other tradespeople. It's obvious even to non-specialists what carpenters and welders and electricians do. But, what exactly does an instrument technician do? What does it mean to configure an instrument, or to calibrate one, or to diagnose and fix problems within a control system?
- Education for this line of work is rare and often of questionable quality and relevance.

The first problem to overcome when searching for jobs is identifying the opportunity by the correct title(s). Here are *some* of the titles by which instrument technicians work under:

- Instrumentation specialist
- Calibration technician or Calibration specialist
- Controls technician or Controls specialist
- SCADA[1] technician or SCADA specialist
- DCS[2] technician or DCS specialist
- PLC[3] programmer, technician, or specialist
- HMI[4] programmer, technician, or specialist
- VFD[5] programmer, technician, or specialist
- Instrument and Electrical (I&E) technician
- Electrical and Instrument (E&I) technician
- Meter and Instrument (M&I) technician
- Instrument and Controls (I&C) technician
- Controls engineer[6]
- Control system designer[7]

It is often the case while reading job descriptions provided by employers that one must pay close attention to the minimum requirements of the job in order to tell whether or not the title of that job actually represents the work of an instrument technician. For example, if the job requires a four-year accredited engineering degree (e.g. Mechanical Engineering, Electrical Engineering, Chemical

[1] "SCADA" is an acronym standing for Supervisor Control And Data Acquisition, referring to control systems gathering process data over a large area, such as those used within the electric power and water treatment industries.

[2] "DCS" is an acronym standing for Distributed Control System, referring to large-scale control systems commonly found within densely-instrumented industries such as chemical processing, petroleum refining, and wood pulp production.

[3] "PLC" is an acronym standing for Programmable Logic Controller, referring to a type of control system often found in manufacturing processes, but present in nearly every industrial facility.

[4] "HMI" is an acronym standing for Human Machine Interface, which are the graphical displays used in SCADA, DCS, and PLC systems giving human operators and technical staff visual access to the data contained within those systems.

[5] "VFD" is an acronym standing for Variable Frequency Drive, a very common technology used to control the speed of large industrial electric motors.

[6] The term "engineer" is widely mis-used, and this is one of those cases. A true *engineer* is a person possessing advanced technical knowledge and analytical skill, capable of creating innovative designs. While instrument technicians are often called upon to devise solutions for unique problems, they generally don't invent new technologies and/or products in the way that a bona fide engineer would do.

[7] The term "designer" is also widely mis-used, and this is one of those cases. This particular misnomer is often found in the contract engineering world, where control system "designers" mostly produce accurate documentation for control systems selected by engineers.

Engineering), and especially if the job requires possession of a state engineering *license*, then it is likely suited for a true engineer rather than a technician. Further confounding the problem is that fact that some employers "bend the rules" of their own minimum requirements and will accept an unusually skilled instrument technician to do engineering work (so long as a state license is not required).

Another confounding factor is blurring of job responsibilities, which is more often the case at smaller companies where staffing is limited. Whereas an instrument technician may have a fairly specific role to play at a large chemical plant where there is sufficient instrumentation in use to warrant staffing specializing in *just that*, an technician working at a small-scale industrial cereal processor may be required to perform routine mechanical maintenance (e.g. lubricating bearings, changing broken or worn belts, aligning machine shafts) and electrical work (e.g. wiring electric lamps and motors, troubleshooting motor control circuits) in addition to maintaining instruments and control systems. The good news here is that a competent instrument technician is a very versatile worker: it is not too much of a stretch for someone knowledgeable in electronic circuits, control valves, and control system programming to rebuild an electric motor, or to configure an electronic motor speed controller, or to replace a broken drive belt. The converse is not necessarily true, and in fact employers often bemoan the fact that it is quite difficult to find mechanics and electricians adaptable enough to learn instrumentation.

It is important for graduates of a technical program in Instrumentation to begin working in their chosen career *as soon as possible* after graduation[8]. Gaps of a year or more between education and related employment are generally viewed with skepticism by employers, because it suggests the person in question is either unmotivated or has unrealistically high expectations. My general advice is as follows: *take the first instrumentation job that pays your bills, and do good work there for at least a year before even thinking about going somewhere else.* More doors will open up for you by doing this than by idly waiting for your dream job[9] to present itself.

The following sections in this chapter describe some of the means available to you for locating employment in the field of industrial instrumentation. Some of these strategies take the form of looking for *any* jobs that are available, while others are more targeted at finding work with an identified employer. Still others are focused on locating employers who *might* hire instrument technicians. These should all be considered in your own job search. Limiting yourself to just one or two strategies means closing yourself off to opportunities.

[8] Here is a sad anecdote. One of my graduates, a young man who enrolled in my college's Instrumentation program immediately after high school, interviewed for an instrument technician job offered by an employer he would have loved to work for. His grades were exceptional, but he was inexperienced and for that reason he was rejected for this job. His interviewers later told me he would be welcome for consideration in the future, but only after gaining some experience. His response to this initial rejection was to give up pursuing any other instrumentation-related jobs and work a low-skill production job at a local manufacturing company in his home town for three years until this same employer advertised once more for instrument technicians. This time, though, his résumé was immediately rejected by the hiring committee and he didn't even get an interview. The reason for this second rejection? He hadn't put his education to work, but instead chose the least-resistance path available to him which was to work a job below his skill level and wait for another chance. To the hiring team, this young man's failure to find work within his chosen field during a time when the job market was very good, or even to relocate outside of his home town, was a sign of poor motivation.

[9] By the way, dream jobs don't exist. *Every* job you will ever have is a mix of good and bad, some better than others, but nothing perfect. Moreover, if you're just beginning your career within Instrumentation, it's quite likely you don't even know yourself what kind of a job you would most like. Remember that this is an incredibly diverse career!

4.1 Job search engines

A variety of internet-based search engines exist specifically for jobs. These include `monster.com`, `indeed.com`, and many others. Some of these websites are specific to certain industry sectors such as petrochemical work, nuclear power, pharmaceutical, and contract construction.

Job search engines are generally the fastest and easiest way to locate employment, once you get past the problem of which terms to use in describing Instrumentation. However, this is a double-edged sword: what is simple and convenient is what becomes over-used by job seekers, which leads to employers receiving a flood of applications through this medium. When you submit your application based on a job search engine result, yours is likely to be one among a great many. This means your résumé needs to be really powerful in order to stand out.

Many online search engines provide the means to automatically send email messages to you listing current job openings in your area of interest. This, of course, is a powerful tool for job searching as it allows you to monitor available jobs without having to duplicate effort.

An important caveat for job search engines is that their postings are not always current. Since advertising is a source of revenue for job search engines, there is a financial incentive to list jobs for longer than they are actually open in order to gain greater viewership. Do not be surprised if you encounter job opportunities on these search engines that are already taken!

4.2 Employment agencies

Some organizations exist expressly for the purpose of helping job seekers connect with local employers, operating as non-profits, as governmental functions, or some combination. These agencies are fantastic resources, as they not only post open job positions, but also provide services such as résumé-writing assistance, mock interviews, and help building professional portfolios.

One such agency operating on a national level is CareerOneStop (`www.careeronestop.com`) which is sponsored by the US Department of Labor.

4.3 Recruiting firms

These organizations are private, for-profit firms poised to link employers with job-seekers. Their services are typically funded by the employer, so as to not pose a financial burden to those unemployed persons who need to find work.

4.4 Union halls

If you become a member of a trade union, you have access to jobs posted at the local union hall (also known as a *hiring hall*). This benefit comes with certain limitations which must be clearly understood. As a union member you must pay regular dues, and you are expected to support your fellow union members and any collective action (e.g. strikes) they may engage in. You are also placed on a list which the hall will use in determining who is called next for open positions, and this list may or may not be adjusted by merit (i.e. technical competence).

The benefits of being in a union include certain benefits (insurance, pension), and generally high wages when there is work to be found. Employers also benefit from a union hall with a list of qualified tradespeople ready to work at a moment's notice.

4.5 Classified advertisements

Most newspapers have a "Classified" section in which companies and individuals may submit advertisements for free. The term "classified" refers to the fact that these newspaper sections are organized according to different advertisement categories: one for jobs, one for real estate, one or more for automobile sales, etc. These postings are necessarily short due to character-length restrictions imposed by the newspaper, but they remain a good source of information on employment opportunities.

Since most modern newspapers have an internet website to complement their paper versions, you may easily search classified job listings for areas outside of your own. This is especially useful if you are interested in moving to a particular region and seek employment in that area.

Don't discount websites such as `craigslist.com` which consist *mostly* of classified listings. This particular website allows you to search by major city in the United States, and will return listings for that city as well as for surrounding areas.

4.6 Trade periodicals

Another "legacy" resource for job seekers are trade journals and other magazine-style publications. Not only do these generally list companies offering a variety of technical services, but the articles contained within cite projects and products associated with a range of employers. When referencing trade periodicals for employment purposes, one must "read between the lines" to find what you're looking for. Very rarely will an article end with "ABC Incorporated is looking for instrument technicians!", but instead you will have to infer employment opportunities based on descriptions of what that company has done and what it is currently doing. In other words, trade periodicals function more as a listing of *employers* than it does a listing of *jobs*. It remains your responsibility to take the next step, which is to investigate companies of interest to you.

A more direct line to employment is often found by consulting the internet websites of trade periodicals, which commonly host job boards where one may search for employment opportunities.

4.7 Corporate websites

Virtually every company hiring instrument technicians has a website, and somewhere on that website is a "Careers" tab or page listing current job openings. This is a valuable way to identify employment opportunities if you already know something about that company. These same websites are also one of the best resources available to you for researching a company, as a part of your résumé-writing process[10].

4.8 Word-of-mouth

A surprising number of open positions get filled simply because one person tells someone else. This is especially true within the world of contract instrumentation work, where one's reputation becomes known among the employers very quickly. I have spoken with the owners of electrical contracting companies new to instrumentation work, who desire very much to "get in" to this word-of-mouth network so that they may hear about the next jobs, the best workers, etc.

Of course, in this digitally-connected age we live in, *word of mouth* consists of much more than just verbal communication. Mobile telephone text messaging, social media messenging, and the like now serve as online channels for people to communicate what they used to be able to say only in-person or over telephone. For those graduating from a formal program of instruction in this field, it is rather easy to set up your own "word of mouth" community with classmates: a means for classmates to share job openings with each other during and after their education.

4.9 Chambers of Commerce

Every major city, as well as many smaller cities, maintains a *Chamber of Commerce* where registered businesses in that area advertise services and connect with clients. These are excellent resources for locating employers, and consequently employment opportunities, within geographic areas of your choosing. Simply do a general internet search for the Chamber of Commerce within the city you're interested in living, then visit that Chamber's website to search for employers. After locating promising employers, visit those employers' websites to search for openings (on the "Careers" page).

Many cities also have business-centered periodicals such as newspapers and journals which you may obtain through Chambers of Commerce. These publications showcase local businesses and business leaders, alerting you to new projects, persons of interest, and industry sectors within that region.

[10] Remember, it is imperative in these modern times to ensure your résumé accurately addresses the knowledge, skill, and/or experience requirements stated in the job posting. You cannot simply write one generic résumé for yourself and expect it to stand out above all the others, because of how companies now screen résumés against their published job descriptions.

4.10 Tours

An easy way to learn about employment opportunities at specific sites, or even within an entire industry sector, is to *tour* a representative facility. Many large industrial employers offer regular tours (sometimes referred to as *open-house* events) where members of the general public may sign up to go through the facility on a specified date and learn about that operation from tour guides.

One need not wait for a public tour, either. Many companies are surprisingly receptive to the idea of giving tours to interested individuals and small groups. In fact, the very act of contacting a company to arrange a tour demonstrates initiative, which of course is highly desirable in any employee. If you know of a particular company you are interested in working for, do not be afraid to contact them about tour opportunities.

4.11 Jobshadowing and Internships

A common experience, especially for people enrolled in a technical program of study, is to spend time on a company's premises learning about their business and the work of an instrument technician without being formally employed by that company. Two common terms used to describe this experience are defined as follows:

- **Jobshadow** – an informal invitation to follow, or "shadow", one or more employees at a job site, usually without pay and usually for a short duration (a week or less).
- **Internship** – a formal arrangement, usually made between a student, their school, and the employer, to provide realistic work experience for little or no pay over some pre-determined span of time.

Either type of experience is extremely valuable for people new to a career, and also looks really good on a résumé. Making yourself known to an employer by means of a jobshadow or internship experience is a sort of *pre-interview* because it demonstrates to that employer what kind of an employee you will likely be, and does so in terms that are more easily believed than what a person claims during an interview. In a phrase, *actions speak louder than words*, and jobshadows/internships are a chance for you to demonstrate who you are by your actions rather than merely by your words.

Schools often assist students in obtaining either jobshadows or internships, but these experiences are also possible to set up without such assistance. In fact, I often have students who set up their own jobshadows without any help from myself, simply by contacting the company they're interested in jobshadowing at, explaining what it is they wish to do there, and arranging times and dates for the jobshadow to occur.

4.12 Informational interviews

One might think of an informational interview as a normal job interview, except in reverse: instead of an employer interviewing you, you are interviewing the employer. The purpose of an informational interview is to learn about the company, identify any job opportunities for you there, and determine if it would be a good fit for you.

The beauty of an informational interview is that it is set up by you. Rather than submit an application and wait (and hope!) for an invitation to be interviewed, an informational interview is something initiated and arranged by you. Of course, the employer must be willing to participate in the interview, but you might be surprised how willing many employers are to do this.

Human Resources (HR) personnel are the ideal point of contact for setting up an informational interview. While it is possible to interview supervisors and other technical employees of a company, Human Resources personnel specialize in identifying talent and are usually more willing to participate.

Prior to requesting about an informational interview, you should do some research on that company and on the specific site whose personnel you wish to interview. No one wants to divert valuable time on the job to answering questions that could have and should have been answered by a simple perusal of the company's website. Simply put, *do your homework first!*

Here is a list of potential questions to ask in your informational interview, and it is by no means exhaustive. Bear in mind that this is a generic list, and that some questions may not be appropriate for the specific employer[11] you are interviewing:

- What is the employment outlook like in your specific industry? How much demand is there for instrument technicians in this company? *Note: do not be surprised if you find yourself needing to explain what an "instrument technician" is, especially if interviewing a non-technical person who may not be familiar with the details and titles of all jobs at that facility!*
- What special certifications, licenses, or credentials are required (or preferred) for technicians to hold?
- Can you estimate future needs for new instrument technicians at this facility?
- What are the typical entry-level job titles and functions (e.g. different "levels" of instrument technicians with different responsibilities)?
- What do you feel is the best educational preparation for this career?
- Have you heard of (*insert your college's name here*), and the Instrumentation program here?
- Does this company offer training to upgrade technicians' skills?
- What are the most significant characteristics of this industry?
- What are the growth markets of this industry?

[11] For example, if the employer you are interviewing is a municipal water treatment facility, it would be foolish to ask "what are the typical production hours for this facility?" because such a facility is obviously running 24 hours a day.

- What are some of the ways in which your industry is changing?
- How do economic cycles affect this industry?
- Does the company have plans for expansion (new buildings, facilities, etc.) in the near future?
- How quickly is this industry/company/site growing?
- What challenges do you see inhibiting the company's profitability or growth?
- What is the typical entry-level salary for an instrument technician in this company?
- What are the salary ranges for higher levels?
- Does this company offer a 401K or other savings plan(s)? If so, is it matching?
- Is there opportunity for technician advancement into engineering and/or management?
- What skills or personal characteristics do you feel contribute most to success in this industry?
- What trends in the field would be most likely to affect someone just entering this career now?
- What is the most important thing that someone planning to enter this career should know?
- What are the typical production hours for this facility?
- What are the typical working hours for an instrument technician?
- Is shift work involved? If so, what is the typical shift schedule?
- Do technicians work weekends or non-day shifts?
- Are technicians expected to be on call during off-hours?
- Do the technicians do most of their work independently or within teams?
- How much travel is involved for technicians at this company?
- Does the company offer tuition reimbursement for employees pursuing advanced degrees?
- How does the company recognize outstanding accomplishments of its employees?
- How does the company foster innovation and creativity in its employees?
- What is the average length of time for an employee to stay in the job you hold?
- What practical experiences would help a new graduate qualify for an entry-level technician position (jobshadowing, internships, etc.)?
- Does this company offer jobshadow or internship opportunities to interested students?
- Will this company help technicians maintain professional memberships in organizations such as the ISA (Instrumentation, Systems, and Automation society)?

- Do you have any written job descriptions of positions in this industry/company you could share?
- What is the best way to apply for a technician position at this company?
- What is the best way to learn of job vacancies at this company?
- If you were conducting a job search today, how would you go about it? Where would open positions be posted?
- If I wanted to apply for a job here, who would the best person to contact?
- Are you currently accepting applications for work?
- Which areas of the company would be most interested in hiring people with my background?
- Would you be willing to answer more questions, by phone or in person, if I need additional advice in the future?

When attempting to contact potential employers, you will usually encounter automated telephone answering systems where you must leave a message for someone to listen to later. One problem with voicemail messages is that they tend to sound unprofessional: vocalized pauses ("um"), meandering sentences, and missing information may leave a bad "first impression" with the person you are trying to contact.

One helpful way to overcome this is to have a *pre-written paragraph* ready to read aloud when leaving a voicemail message. This will help you overcome anxiety when faced with having to leave a voicemail message ("What do I say?"), shorten the message by eliminating wasted time, and ensure no critical information is omitted.

Your message should contain the following information, at minimum:

- Your name, and how (and when!) you may be reached (e.g. phone number)
- The purpose of contacting this company (to explore career options there)
- (Optional) *a statement describing your interest in this company*
- Conclude with a repeat of your contact information (e.g. phone number)
- A friendly sign-off (e.g. "Have a nice day")

An example paragraph is shown here, which I used when contacting multiple employers based in California several years ago:

> Hello. My name is Tony Kuphaldt, and I'm an instructor of Instrumentation and Control Technology at Bellingham Technical College in Washington state. My telephone number is 360-752-8477.
>
> I have a class of 19 students ready to graduate this June with their two-year Associates degree in Instrumentation, and some of them are specifically interested in moving to California. I would like to explore job opportunities with your company for the benefit of these students. I believe these students' skill set would be valuable to your operation, and I would like to see if this year's graduates could fulfill some of your technical staffing needs.
>
> Again, my telephone number is 360-752-8477. Please feel free to contact me about any open positions you may have at the moment, or that you predict you may have later in the year.
>
> I look forward to discussing possibilities with you. Thank you very much!

4.13 Digital "smokestacking"

I once read an article in a technical journal written by an instrumentation salesperson discussing the "good old days" of technical sales, when many of his first contacts were done in person rather than by telephone or by internet communication. This salesperson fondly remembers driving his car along major highway roads looking for tall smokestacks, which served as markers for any number of heavy industries. Once a smokestack was spotted, he would pull off that road, locate the facility, and knock on their front door to begin a conversation with personnel there who might have been interested in his products.

This practice was called "smokestacking" and apparently it worked well enough for some technical salespeople to sustain a living. While this may seem quaint in our age of digitally connected individuals and businesses, and perhaps even irrelevant to the problem of locating employment, this concept should not be dismissed out of hand. If you wait until a job becomes posted somewhere (e.g. in a job search engine, classified advertisement, or by word of mouth), you will miss out on many opportunities. Searching out prospective employers and making first contact with them is a valid strategy for job searching, and to do that you must first identify where those employers are located. Smokestacking is one way to do this.

What I'm referring to as *digital* smokestacking consists of using satellite-mapping applications on the internet to find large industrial sites. My personal favorite is `Google Maps`, which also allows simple searches by industry type and company name. This technology will surely become more powerful as time goes on, making it ever more useful for locating prospective employers. A satellite view of an industrial site can be extremely informative, revealing such details as:

- Production capacity (based on the acreage of the site)
- Transportation modes (e.g. truck, rail, ship, pipeline) for feed and product
- Energy sources (e.g. combustion furnaces/boilers, electricity)
- Certain process design details (e.g. distillation columns, reactor vessels, clarifying tanks, conveyors, heat exchangers, settling ponds, etc.)

An example of how satellite imagery can help you learn more about an industrial site is as follows. Suppose you locate a paper mill in a particular city, and found its satellite image of that mill on one of these mapping applications. Looking closely at the image, you stacks belonging to a boilerhouse (revealed by whisps of steam from pressure-relief valves on the top of that structure), and what appears to be a water-treatment pond of some sort. These are all standard features of any pulp mill. You also happen to notice a railroad track with a number of parked tank cars on site, as well as a conspicuous lack of any wood chip piles. From these details you may deduce that the facility in question receives liquid wood pulp from some other facility, and merely transforms this pulp into paper. A full *pulping* operation would sport a large wood chip pile as its feedstock supply. This information is useful for several reasons: first, it means this paper mill will smell much better than most paper mills due to the lack of chemical digestion of the wood chips (releasing hydrogen sulfide gas), but it also means quite a bit less instrumentation will be used since almost none of the chemical processes of a full pulping mill exist at this facility.

Another example is described here. Suppose you locate a wastewater treatment facility in some city, and the satellite image reveals several open circular "clarifying" tanks, which are typical of

any water treatment plant. However, suppose you also notice a couple of large closed-roof circular vessels on the site, and what appears to be small smokestack. This is most likely a *digester* vessel used to anaerobically break down the wastewater solids in order to reduce their volume and produce *biogas* (mostly methane) as a fuel for steam boilers or engines. Not all wastewater treatment plants utilize anaerobic digesters, but those that do have an increased amount of instrumentation necessary to manage the digester conditions necessary for safe and efficient production of gas, which means a greater likelihood of employment for you at that facility.

4.14 Summary

As you can see, there are many alternatives to using job search engines and classified advertisements when searching for employment opportunities. The existence of so many alternatives mean many of them are relatively unexplored by job seekers. This is good for you because these less-popular means are less likely to be saturated by others looking for work.

An important principle to bear in mind when actively reaching out to companies is that the more personal the contact, the more effective your efforts will be. As I like to advise my students, *"A telephone call is worth a thousand email messages, and a personal visit is worth a thousand telephone calls"*. No matter how sophisticated our communications technology becomes, in the end the goal of all employment searches is to make a persuasive connection to a live human being. Never forget this essential human element.

I would like to end this chapter with an anecdote from my own life. Shortly after beginning a two-year program at a technical school I began a search for part-time work to help pay for living expenses. I was willing to do almost anything, but I preferred something technical because at that time I had a strong background in electronics as a hobby and I was studying a technical subject at school. My first stop was at a Radio Shack store, where I inquired about work as a repair technician. To my pleasant surprise, the store's owner was immediately interested because his former repair technician left his job to work for another company in town (which he mentioned by name), and he really needed someone else to fill that job. My heart sank, though, when he told me the only working hours fell during my school day.

Walking away from the Radio Shack store, I made a mental note to look up the phone number of that other company when I got home. I figured anyone qualified enough to do that job well would only leave for something better, which likely meant an equally or more technical job for more pay. When I reached my apartment I got my phone book and found in it a single phone number and street address for that company. It happened to be located between the school I attended and the apartment where I lived, and so I planned to stop by the next day.

When I visited this facility, it was a plain sheet-metal building located on the edge of the local airport runway. As it turned out, this was only one out of several facilities run by this particular company, some of the others being larger and better-equipped. Walking inside, I immediately smelled cutting oil and tool coolant: evidence that this was a machine shop. The receptionist told me there were no open jobs at the time, but that they do periodically hire machinists and other skilled persons, and recommended I complete a job application for their files. At the time I didn't have much to offer in the way of ability except for general familiarity with machine tools and a hobbyist's background in electricity and electronics.

The very next day I received a telephone call from the maintenance foreman of that facility asking me to return for an interview. As it so happened, he was overseeing a major machine tool retrofit project and needed someone to do soldering and other basic electrical work. He had not yet posted a classified advertisement for such a person, but was planning to. When I arrived for the interview, we had a very pleasant conversation about the project, the facility's products, my interest in their operation, my availability for work, and other details. At the end we shook hands, and Monday of the next week I was officially hired.

This was not, to put things lightly, my idea of a dream job. Although the opportunity to have an income and to gain valuable technical experience was certainly appreciated, the working conditions were less than ideal. The job paid only $6 per hour (in the year 1987), provided no benefits, and

the company was run by a fellow who openly mocked[12] his employees. However, working at this job turned out to be key to landing my *next* job, as it seemed most industrial employers would have been extremely reluctant to hire a 19-year-old instrument technician without any work experience. It was also a great experience because of my co-workers who were friendly, helpful, and taught me many practical skills. This was another valuable life-lesson for me: opportunities are rarely perfect, but they don't need to be in order to pay off handsomely in the future.

There are many different lessons one could draw from this story, but the one I would like to emphasize is that you just never know what job opportunities you may miss if you limit yourself to *posted* jobs. Here was a job that paved the way for my future career while paying a good portion of my living expenses while in school, which I may never had even heard of had I not taken initiative to knock on their door.

This lesson is not an isolated incident, either. Time and time again I have witnessed my own graduates do the same: land a job simply because they took initiative to make first contact with an employer. Of course this strategy doesn't always result in getting hired; in many cases the applicant discovers no positions are available. However, it has proven successful often enough[13] for me to advise this as a strategy to all my students. Honestly, what do you have to lose by trying?

[12] He would occasionally visit our facility, referring to us as "children" and to our breaks as "recess". The times he spent in jail for tax evasion were welcome, because things always seemed to run smoother when his wife took over operations for him. According to my co-workers this state of affairs was a considerable improvement over earlier years, when in addition to these offenses it was commonplace for employees' paychecks to bounce. At least no one had to rush to the bank on payday anymore to cash their check before the account ran out!

[13] An oft-quoted statistic claims that approximately 80% of jobs are unpublicized, but this seems to be more fiction than fact, especially in the internet age of job search engines where posting open positions far and wide has become very easy for employers to do. However, I can tell you that taking initiative in making first contact with an employer you're interested in working for is productive in the following scenarios: (1) when the company in question is small and lacks a recruitment budget, (2) when a company knows they need to hire more people but they haven't advertised that need *yet*, and (3) when a positive contact inspires an employer to hire someone to fulfill a need they were not yet consciously aware of.

Chapter 5

Résumés and Cover Letters

A résumé and cover letter exist for one purpose: *to convince an employer to give you an interview.* The specific purpose of a résumé is to concisely summarize your abilities, while the specific purpose of a cover letter is to express your interest in working for that employer. Both the résumé and the cover letter should be limited to one single-sided page of text each[1]. The résumé and cover letter together serve as a starting point for that interview, providing specific examples to discuss of your interest in and qualifications for the job. This exploration of résumés and cover letters will assume a job in the field of Instrumentation, and will contain specific guidelines for this career.

[1] Unless you have extensive work experience and other relevant accomplishments to note in your résumé, a single page (one-sided) should be considered maximum. My own résumé based on over three decades of technical work experience is only two pages long (i.e. one sheet of paper, printed on both sides).

Let's begin our study of résumés with these two lists:

Essentials of a good résumé

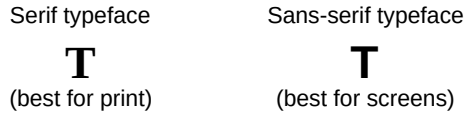
- Your name and contact information
- Your relevant educational qualifications
- Your relevant work experience
- Details of your knowledge and experience *directly applicable to this job*

Prohibited items on a résumé

- Spelling errors, grammatical errors, and incorrect technical terms
- Inconsistent or messy formatting
- Use of colored text or novelty fonts (typefaces)
- Information irrelevant to the job sought
- Any embellishments or otherwise inaccurate statements
- Self-assessments (e.g. "Hard worker" or "Resourceful")

Always bear in mind that *content* is more important than *format*. Many résumé guides elaborate on formatting styles, but my universal experience with employers hiring instrument technicians is that résumé style counts for little. If you were applying for a job at a newspaper doing page layout, style and formatting would be very important, but not in this field.

One notable exception with regard to formatting is your choice of font, or more properly *typeface*[2], which greatly affects the presentation of your documents. *Serif* typefaces with their small "tail" adornments at the vertices are easier to read when printed on paper, while *sans-serif* typefaces lacking these additions are easier to read on illuminated screens:



Examples of good serif typefaces include Garamond, Cambria, and Bookman Old Style. Times New Roman is also a serif typeface, but is over-used and considered by some to be ugly. Examples of good sans-serif typefaces include Helvetica, Calibri, and Arial. Always avoid cursive-style ("script") typefaces, monospaced typefaces such as Courier, and novelty typefaces such as Comic Sans. Font size should be 12-point, except perhaps for your name and/or section titles which may be larger.

Please note the last bullet-item on the "Prohibited" list: *self-assessments*. This may strike you are odd, given that the purpose of a résumé is really self-promotion. However, only a moment's

[2]Typeface refers to a "family" of characters. Font refers to modifications of those characters within a typeface family, such as *italic*, **bold**, and sizing.

worth of thought is necessary to discover why positive self-assessments look bad on a résumé: they are worthless because *of course people will say great things about themselves!* In other words, self-assessments are worthless because the source is biased.

How then do you accomplish self-promotion on a résumé without self-assessment? The answer is simple: cite concrete examples of accomplishments *proving* those same qualities. If you think you are a hard worker, for example, show that to be true by citing actual experiences where your hard work was necessary to the achievement. If you consider yourself to be resourceful, prove it by citing examples of when your resourcefulness was on full display. If cannot recall any life experiences illustrating such attributes, then you need to begin engaging in activities which will develop and showcase these traits, and do it *now*.

A sign of the times with résumés is that any submitted to an employer in electronic format (e.g. Word or PDF document) will likely be scanned by a computer before any human being sets eyes on it. This computer will be sifting through your document looking for words and phrases matching the posted job description. Many résumés will be rejected based on low match scores, which means if you ever want your résumé to hit the desk of an actual human reader it's going to have to be tailored to the specific job you are applying for. The reason for this is rather simple: electronic job applications mean employers are inundated with more résumés than they ever faced in the days of paper submissions, and this necessitates a screening mechanism which won't burden their Human Resource departments[3]. An easy way for employers to cull this virtual pile of résumés is by letting a computer figure out who among the applicants actually bothered to read the job description and write something relevant to it. Federal agencies use a similar strategy to cull applicants: force all of them to complete an application form containing dozens of pages and hundreds of entries/selections. Those who can't accurately complete the form are automatically rejected prior to any interviews taking place.

It should go without saying, but just to be clear: *tailoring your résumé and cover letter to a particular job description does not grant you license to embellish or otherwise misrepresent yourself!* Absolutely everything you write on your résumé and cover letter needs to be completely true[4] and demonstrable. What is meant by "tailoring" is rather omitting details of your education and experience that are not as relevant to the particular job being sought, so that the precious space

[3]This is assuming the employer even *has* an HR department. A common trend is downsizing of HR staff, which means companies often outsource their HR needs to third-party services which handle job application screening for multiple clients. This is another sign of the times, and it is a point of frustration for many job seekers because it also tends to slow down the screening process. It is not uncommon for my graduates to receive positive responses from companies *five or six months following their application!*.

[4]One memorable anecdote on résumé accuracy comes from my own experience. As graduation neared for my classmates and I at the technical college, we all set to work drafting résumés and cover letters. As is natural for students to do, we often compared each others' documents in order to get ideas on presentation and format. Something that struck me from these observations was that nearly every one of my classmates mentioned *microprocessor architecture* as something they learned in school. This puzzled me, as our only direct experience with microprocessors at school was developing simple assembly-language programs for the Intel model 8080 (8-bit) processor. The term "architecture" deals with the internal organization, data flow, and overall design of the microprocessor chip itself, which was well beyond the scope of writing simple code. Our textbook, however, had one chapter in it with that title, and so it seemed many students were willing to list that as a knowledge area when in fact we had learned very little on that topic. Perhaps they believed it sounded impressive. Whatever the case, it is very risky to list something on a résumé or in a cover letter for which you are not completely competent. Technically savvy interviewers *will* ask you to elaborate on qualifications claimed in your documents, which means you had better only list things you're strong in, or risk failing an interview for overstatement. Also bear in mind that people have been fired from their jobs after their employers learned they lied on their résumés, so the risks of misrepresentation don't end after a successful interview!

may be devoted to your *most* relevant qualifications.

Elements of both good and bad résumés will be highlighted through examples. These examples will be shown in ugly monospaced typeface simply for the purpose of illustrating how content is more important than formatting. Your résumé should *look* nicer than any of these examples, but remember that technically-minded people care far more about substance than style.

Cover letters, similarly, have essential and prohibited elements:

Essentials of a good cover letter

- Addressed to a specific person at the company
- An explanation of how you discovered the company and/or job opening
- A description of your interest in working for this company
- Details revealing you have researched this company well
- An expression of appreciation for their time and attention
- Your name and contact information
- Your personal signature

Prohibited items on a cover letter

- Spelling errors, grammatical errors, and incorrect technical terms
- Inconsistent or messy formatting
- Use of colored text or novelty fonts (typefaces)
- Information irrelevant to the job sought
- Any embellishments or otherwise inaccurate statements
- Self-assessments (e.g. "Hard worker" or "Resourceful")
- Informal verbiage or tone
- Repeated sentences beginning with first-person pronouns (e.g. "I" or "My")

A cover letter is first and foremost a *business letter*, and should follow all the conventions of such. It should be *highly* specific to the job or company you are interested in, even more so than your résumé[5]. Like all well-written letters, it should sound good when read aloud: the presentation should be similar to how a person might actually speak to another in a business environment.

In summary, the purpose of your résumé and cover letter is to secure an interview. The résumé explains why the company should be interested in you, and your cover letter explains why you are interested in the company.

[5] While customizing your résumé to the job in question is important, there are likely portions of any good résumé that will be generic to all Instrumentation jobs. A cover letter, on the other hand, needs to be highly specific to one job: addressing a specific person at that company, describing how you learned about the position or the company, etc.

5.1 Résumé examples for recent graduates

Here is an example of a good resume for a recent graduate of an Instrumentation program, with no prior industrial experience, applying for a job in an air separation facility (where air is separated into high-purity oxygen, nitrogen, carbon dioxide, and other gases):

```
                        Megan A. Prospective
                   1234 Main Street  (City, State)
              (123)-555-1212    megan_prospective_123@gmail.com

EDUCATION:
  Sep 2015 - Jun 2017 Centerview Technical College
  ATA degree in Industrial Automation and Control Technology
  GPA = 3.21/4.0, perfect attendance

TECHNICAL KNOWLEDGE AND SKILLS:
  * Calibration of both analog and HART field instruments: pressure, level,
    temperature, flow, and NDIR gas analyzers
  * Control valve rebuilding (Fisher), positioner calibration and alignment
  * Siemens S7-1200 PLC programming
  * Troubleshooting faults in control systems built and documented in lab
  * Physics of gases and liquefied vapors, phase changes, latent and sensible
    heat calculations, phase diagrams, thermodynamic degrees of freedom
  * Software: AutoCAD, SPICE circuit simulator, Emerson DeltaV Explorer,
    Emerson DeltaV Operate, Emerson AMS, Siemens Step7, Excel, Word, Access

WORK EXPERIENCE:
  Jan 2013 - Jun 2017 Saucy's Pizza -- Night shift supervisor
  * 40 hrs/week prior to school; 30 hrs/week during
  * Manage crew of 5 employees, organize work schedules, maintain inventory,
    open and close store
  * Implemented principles of Lean Manufacturing into store procedures (2016)
  * No work absences for the last three years

  Mar 2012 - Jan 2013 Saucy's Pizza -- Waitress
  * Waited on customers, cleaned tables, prepared beverages, placed orders,
    operated cash register, balanced till at end of every shift

OTHER SKILLS AND QUALIFICATIONS:
  * Fluent in conversational Spanish
  * Certified in First Aid and CPR (Feb 2016)
  * Maintain current US passport, willing to travel
  * Academic transcript and project portfolio available upon request
```

Reviewing this résumé, we find many positive aspects worth highlighting:

- Note how the applicant's name and contact information is prominently featured at the top of the document, easy to read and difficult to miss.
- Note the perfect spelling throughout. This is particularly important for technical terms (e.g. liquefied, alignment, analyzers). Mis-spelling any of these terms signals unfamiliarity to any reviewer familiar with instrumentation, making it look as though the résumé writer simply inserted words into their resume that might sound impressive.
- Note the excellent grammar throughout. The tense (past, present) of every verb is appropriate to each statement: past accomplishments use past-tense verbs (e.g. implemented, cleaned, placed,), while present activities use present-tense verbs (e.g. manage, maintain).
- Consistent use of punctuation: each bullet-item lacks a period at the end. Placing periods at the end is fine, and so is omitting them, but inconsistent use betrays a lack of attention to detail and just looks ugly. If any line contains multiple sentences, you *must* use periods!
- The work experience, while admittedly not industrial or technical in nature, is relevant because it highlights the applicant's ability to maintain schedules, be punctual, manage subordinates, and in general bear substantial responsibility within a business environment.
- Note how the knowledge and skill section mentions instruments, systems, and computer software one might expect to encounter at an air separation facility. Nothing in this section appears extraneous to the job. Specific topics from the applicant's education in physics germane to air separation (liquefaction of gases, phase diagrams, thermodynamics, etc.) show that the applicant understands the nature of the industry and the relevance of her technical studies. In other words, *it is obvious she has done her homework*, and this speaks well for her potential value as an employee.
- Note the complete absence of any subjective claims. The applicant never describes herself as a hard worker, but she shows this to be true through her outstanding attendance and work schedule concurrent with being a full-time student. She also demonstrates responsibility and initiative through her work experience. Her possession of a passport and willingness to travel, as well as her multilingual capabilities speaks to her ability to learn different cultures and her openness to new experiences. Even if the job never requires travel or communication in a language other than English, these traits are still valuable in other ways.
- Note how the applicant also has her academic transcript and project portfolio ready to show employers. It is not necessary to say "references available upon request" anymore, since checking references is standard operating procedure for the vast majority of employers. However, one should always have a list of professional references ready to submit to an employer when seeking work.

Here is another example of a good resume for a recent graduate of an Instrumentation program. In this example the writer has no work experience at all, and is applying for the same job in an air separation facility (where air is separated into high-purity oxygen, nitrogen, carbon dioxide, and other gases):

```
                        Jonathan A. Prospective
                     5220 Main Street  (City, State)
                  jon_pro335@yahoo.com  (222)-555-8787

EXPERIENCE:
  * Interned at Dryson Controls during January 2015, a licensed Emerson
    products distributor and UL 508A panel shop.  Wired DCS panels and
    installed Fisher DVC6200 valve positioners.
  * Designed and built an air pressure control process using a Siemens
    S7-1200 PLC control system, Honeywell ST3000 pressure transmitter, and
    Research Control valve to maintain air pressure at a setpoint.
  * Programmed an Emerson ROC800 SCADA controller to monitor weather
    conditions outside of the college's lab, using a blend of Foxboro,
    Rosemount, and Yokogawa 2-wire transmitters to sense variables.  Set
    up an OPC client to read data from the SCADA system and display
    weather conditions on a networked PC.
  * Set up multiple PC networks for online gaming events: configuring
    routers, setting IP addresses, using PING to diagnose network
    connections, testing connection bandwidth, and providing technical
    support to teammates over telephone.

TECHNICAL KNOWLEDGE AND SKILLS:
  * Calibration and ranging of transmitters both smart and analog.
  * Creating loop diagrams and P&IDs using AutoCAD and Rhino.
  * Diagnosing electrical circuits using Fluke digital multimeters.
  * Applying physics principles to the analysis of fluid systems: Ideal Gas
    Law, Bernoulli's Equation, Pascal's Principle, and steam tables.

EDUCATION:
  Sep 2015 - Jun 2017 Centerview Technical College
  ATA degree in Industrial Automation and Control Technology
  GPA = 3.53/4.0

OTHER SKILLS AND QUALIFICATIONS:
  * Served on Centerview Technical College ASB Senate Sep 2016 - Jun 2017
```

For someone in this position, the biggest challenge is to convince an employer to take a chance given a complete lack of actual job experience. This is not an impossible task, but it is not easy. Note how this person addressed that problem in his résumé: by beginning with *experience* rather than with education. Although all of this experience was gained in school (and on an internship) rather than by working an actual job where he received a paycheck, it is still practical experience which is the point which needs to be strongly conveyed to any technical employer.

Note also how the internship is featured prominently in this résumé. For people lacking work experience, jobshadows and internships can be game-changing experiences. Not only do they provide practical experience prior to employment, but doing good work during a jobshadow or internship may lead to good references from supervisors and co-workers at the company. Again, the emphasis here is on *experience*: how to gain as much as possible, and how to clearly communicate what you have gained to an employer who may be skeptical of your lack of direct employment experience.

This example résumé models practical ways to communicate experience to an employer. Note how in the internship line we read details of the company (Dryson Controls) meaningful to people familiar with instrumentation: it is a licensed distributor of Emerson products (Emerson being a major industrial instrument manufacturer, who licenses certain businesses to exclusively represent the Emerson product line within a geographic region), and it is also a UL 508A panel shop (a certification that this facility is authorized to design and construct panels meeting Underwriter's Laboratories standards for industrial electrical controls). The work done at this shop is practical as well: wiring Distributed Control System (DCS) panels and installing a particular model of Fisher control valve positioner.

The next two bullet points under the "Experience" section of the résumé highlight specific projects completed by this person while they were a student in technical college. Pay close attention to the level of technical detail conveyed in these points, which is far more than what we saw in the previous (good) résumé. Again, the idea here is to convey to any prospective employer that this person has actual experience working with industry-standard equipment and systems, and can speak to the technical details of doing so. A common tendency among graduating students is to simply make bullet-point lists of study topics and course names from school, but descriptive paragraphs of technical projects convey all the same points while also communicating *hands-on experience* to the reader.

The last bullet point in the "Experience" section highlights technical competence applied (and possibly gained) outside of school: in this case, computer networking in a video game environment. It would be a bad thing to simply document video game *playing* experience, but here we see this hobby has practical merit in the form of personal computer (PC) network configuration, testing, diagnosis, and technical support delivered over telephone. Again, the over-arching principle at work in this résumé is to leverage any and all hands-on experience as compensation for a lack of actual paid work experience.

Finally, under the "Other Skills and Qualifications" section of this resume we see the writer has cited their participation in the Associated Student Body (ASB) governance while at the technical college. While this at first may seem to be completely unrelated to the field of Instrumentation, the relevance is with "soft skills" rather than "hard" technical skills. Serving as a Senator means having to communicate with constituents, maintain deadlines, attend meetings, listen carefully, and other very important skills any employee should possess. Again, this may not be exactly the same as paid work experience, but for a person in this position who has no such work experience it is the next best thing. Volunteer experience is similarly useful both for gaining experience and as a "selling

point" on a résumé.

In summary, if you are in the same position as the writer of this résumé, you have two tasks to complete: (1) gain as much practical experience as you can while in school, and (2) document that experience as clearly and as compellingly as you can when applying for jobs.

Here is an example of a poor resume for a recent graduate of an Instrumentation program, applying for the same job as the other recent graduates (Megan and Jonathan) in an air separation facility:

```
                        Robert F. Prospective
                    4321 Main Street  (City, State)
                (123)-555-2121    reeferdude420@yahoo.com

EDUCATION:
  2015-2017 Centerview Technical College
  Controls degree
  GPA = 3.61/4.0

  2007-2011 Centerview High School
  * Track and Field varsity team

TECHNICAL KNOWLEDGE AND SKILLS:
  * Studied pressure, level, tempature, flow, chemistry
  * Fisher valves and digital controllers
  * Calibated lots of transmitters and sensers
  * HART calibrators, troubleshooting
  * I/P transmitters
  * English 101, Psychology 105
  * Rhino 3D, excel, word. adobe pdf, autocad; emerson deltaV,
    siemens plc, access

WORK EXPERIENCE:
  2014-2015 Safety watch at Tesoro refinery
  * Hard worker, reliable

  2011-2012 NAPA Auto Parts
  * Detail-oriented
  * Customers liked me

  2012-2014 Joes Garage and Detailing
  * Learned a lot about engines

OTHER SKILLS AND QUALIFICATIONS:
  * Welding, painting, sheet metal work
  * Tune-ups on cars
  * Hot work permits
  * Standard and metric tools
```

Reviewing this résumé, we find many problems worthy of note:

- Note how the applicant's email address is grossly unprofessional. The abundance of spelling errors (e.g. *tempature* instead of temperature, *sensers* instead of sensors) is also unprofessional.
- The title of the degree is incorrect. While the previous two résumés correctly listed the degree as an ATA in Industrial Automation and Control Technology, this résumé simply says "Controls degree" which gives the reader the impression that Robert doesn't even know what program he's enrolled in.
- Note the technically incorrect terms used (e.g. HART *calibrator* instead of HART communicator, I/P *transmitters* rather than I/P converters or I/P transducers). Note the uncapitalized software title, which is incorrect because these are proper nouns.
- Note the grammatical errors (e.g. *Joes* Garage instead of Joe's Garage, incorrect punctuation marks separating some of the listed software applications) as well as inappropriately informal wording (e.g. *lots* of transmitters, learned a *lot* about engines). This might be how you converse with friends, but it is definitely not the way you communicate in business.
- Note how the employment listing is not in chronological order. This might be appropriate if the ordering is based on relevance to the job sought, but there are no details suggesting why this would be true. Instead, it just looks as if the applicant didn't pay close attention to how their employment details were listed.
- This applicant's work experience, while possibly more relevant to a technical field like Instrumentation than the prior applicants (Megan and Jonathan), is so lacking in detail that it conveys little merit. Any reviewer comparing Megan's résumé against Robert's would consider Megan's work experience in the pizza restaurant to be more compelling than Robert's work experience in the auto parts store, mechanic's garage, and oil refinery. Her work experience demonstrates responsibility and professionalism, while his suggests little more than collecting a paycheck. This is a missed opportunity for Robert to showcase relevant experience. The same may be said of his Other Skills and Qualifications section which is similarly vague.
- Another notable detail about this applicant's work experience is the lack of detailed starting and ending dates. There is no need to list specific *dates*, but failing to list the year *and month* each job began and finished may be viewed by some employers as a means to hide employment gaps[6].
- This applicant's educational achievements reveal some important details. His GPA is good, and in fact better than Megan's, but there is no mention of attendance which is generally given greater consideration by employers. Note also how there is no overlap between work and school, which suggests he was not burdened with working a job while studying Instrumentation (unlike Megan who worked part-time while going to school). This applicant's mention of high school, as well as being on the varsity Track and Field team, is completely irrelevant to the job at hand. Secondary education, unlike technical college, is something everyone does. For

[6]Gaps in employment are frowned upon by most employers of tradespeople. While not always the case, periods of unemployment can indicate poor motivation or work ethic. If you have any employment gaps, prepare to be questioned about them during interviews!

all the reviewer knows, making the varsity team had more to do with natural athletic ability than to any positive character traits.

- Note how the knowledge and skill section is sparse and lacking in detail. Employers aren't interested in bullet-point lists of topics studied, *unless that list demonstrates an understanding of the education's relevance to the job being sought.* Compare Megan's knowledge and skill list to Robert's: Megan connects specific topics learned in school to the applications found at an air separation plant, while Robert merely lists generic topics. Jonathan's "Experience" section is even better, in how it provides very detailed descriptions of the work done in technical school.

- All points listed in the knowledge and skill section need to be specific to the job. No technical employer cares that you took English 101 or Psychology 105, although they *do* care about your ability to read and write well and your ability to work well with others. Remember that you only have a single page of text to make your best case for why you should be hired – don't waste any of it describing coursework that *every graduate* has finished.

- Note the subjective claims in the Work Experience section, which *might* be true but are rendered moot by the fact they come from a biased source (Robert). The best way to demonstrate positive attributes is by citing actual *accomplishments* where these attributes are necessary, like Megan did in her résumé and like Jonathan did in his. This is another missed opportunity for Robert.

You will note that none of these résumés included an *objective*. Generally speaking, an objective statement is not necessary unless the position sought is highly specific and/or liable to be confused with another open position. An objective becomes completely redundant in the presence of a well-written cover letter, the purpose of which is to express why you are interested in the position.

Veterans of the armed forces in the United States automatically have access to a document listing training and assignments while serving. This is called a *DD214* form[7], and copies of it should be ready to mail or hand in person during an interview.

[7] The official title of this military document is a *Report of Separation*, DD form 214. It details such information as the entry and release dates of the service member's service, home address(es), last duty and rank, education, specialized training, decorations and awards, and discharge status.

5.2 References

One of the final steps an employer takes prior to hiring a new employee for any job bearing significant responsibility is contact people who have worked with that person in the past. These people are *references* for the prospective employee, and what they say can make or break the deal. It used to be customary for résumés to say "References available upon request" near the end just in case the employer wished to contact references, but now the practice of contacting references has become so common that it is expected all applicants will have a list of references ready upon request.

When an employer contacts a reference, their goal is the same as when reading résumés and cover letters: to ascertain the fitness of the prospective employee to the job. The major difference with references is that the source is far less biased, and therefore more likely to yield an honest answer. Questions that will likely be asked of the reference are similar to questions asked during an interview, and may focus on behavioral tendencies, technical skill, or more likely than not some combination of those two.

It is very important that you carefully choose who you list as references. First and foremost, you must contact each and every listed person to obtain their consent. Listing someone as a reference without first acquiring their permission is a huge mistake. Few things look worse for the applicant during a job screening process than a reference who was unaware they were listed as a reference[8]. When asking permission to list someone as a reference, be sure to inquire whether you need to sign any release form legally permitting that person to comment on your performance. Professional educators, for example, are required to have a FERPA[9] form signed by the student in order to release certain details of that student's educational record to anyone outside of the school.

Each of your references should be able to speak in detail to your technical capabilities, work ethic, general attitude, creativity, and other important facets of who you are as an employee. Direct supervisors, co-workers, and college instructors generally make good references. Family members, friends, and acquaintances do not. For young adults lacking significant work experience, one of the best references you can have is a supervisor at a company where you have "jobshadowed" or interned doing instrumentation-related work. Professional observation and testament of your knowledge, skill, and character in action constitutes one of the major benefits of participating in jobshadows and/or internships.

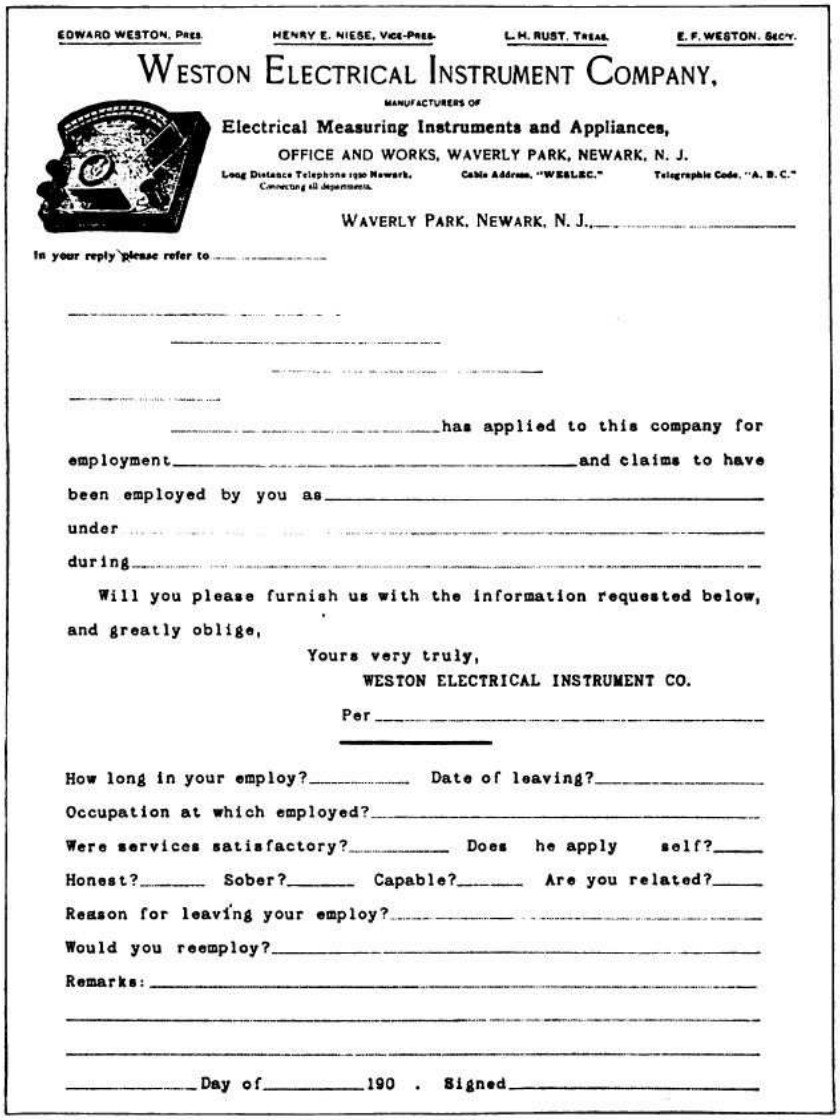
Three is generally considered to be the minimum number of people to list as references, with five as a maximum. Try to have broad representation on your reference page: don't list only instructors, or only co-workers, or only supervisors. Each of these people should be given a copy[10] of your résumé for their own reference.

[8] I once had a student who set up an informational interview with an employer, then listed the person they interviewed as a reference when applying for a job at that company! This was grossly unprofessional, seeing as how that person didn't know anything about the student's capabilities or character, and was never asked to serve as a reference. In this particular case the results were disastrous for the student: he was told to never apply to that company again, *ever*.

[9] The Family Educational Rights and Privacy Act of 1974.

[10] Just one copy is sufficient, even though you will be tailoring each of your résumés to each job you apply for.

A job reference form from the early 1900's[11] used by the Weston Electrical Instrument Company reveals what was, and still is, the purpose of a reference:



EDWARD WESTON, Pres. HENRY E. NIESE, Vice-Pres. L. H. RUST, Treas. E. F. WESTON, Secy.

WESTON ELECTRICAL INSTRUMENT COMPANY,

MANUFACTURERS OF

Electrical Measuring Instruments and Appliances,

OFFICE AND WORKS, WAVERLY PARK, NEWARK, N. J.

Long Distance Telephone 1900 Newark. Connecting all Departments. Cable Address, "WESLEC." Telegraphic Code, "A. B. C."

WAVERLY PARK, NEWARK, N. J., _____

In your reply please refer to _____

_____

_____

_____

_____

_____has applied to this company for employment_____and claims to have been employed by you as_____ under _____ during_____

Will you please furnish us with the information requested below, and greatly oblige,

Yours very truly,
WESTON ELECTRICAL INSTRUMENT CO.

Per _____

How long in your employ?_____ Date of leaving?_____

Occupation at which employed?_____

Were services satisfactory?_____ Does he apply self?_____

Honest?_____ Sober?_____ Capable?_____ Are you related?_____

Reason for leaving your employ?_____

Would you reemploy?_____

Remarks: _____

_____

_____

_____Day of_____190 . Signed_____

As you can see, this reference form begins with claims provided by the job applicant regarding their previous employment. The reference first and foremost verifies that all the claims are indeed correct, and then proceeds to comment on the applicant's important qualifications: competence, motivation, honesty, etc.

[11] This gem was located on page 111 of volume 31 of *Cassier's Magazine* published in the year 1907, in an article entitled "Modern Factory Management" written by Egbert P. Watson.

Here is an example of a reference page for the graduating student with the well-written résumé. All reference pages should follow this same general format, listing at least three people listed who can reliably attest to your character and fitness for the responsibilities of employment:

```
Megan A. Prospective
1234 Main Street
(City, State)
(123)-555-1212
megan_prospective_123@gmail.com

          REFERENCES

Jonathan Williams, instructor
Centerview Technical College
(City, State)
(555)-303-4452 [office]
jwilliams@cvtc.edu

Miranda Knight, owner
Saucy's Pizza
(City, State)
(442)-821-7092 [cell]
miranda@saucyspizza.com

Evangelista Carlos, instructor
Spanish department
Toonica High School
(City, State)
(920)-826-3302 [office]
e_carlos@ths.edu
```

Note how the reference page, just like the résumé, begins with the applicant's name, address, and full contact information. The goal here is to leave no doubt whatsoever in the employer's mind who you are and how to contact you!

It is common practice for employers to check references, but even so it is customary to omit the reference page when submitting your résumé and cover letter. When the time comes to check references, the employer will contact you to request references. You should always bring a copy of your reference page, as well as other supporting documentation[12], to any interview.

Similar to references are *letters of recommendation*. Such a letter is written by someone with the same qualifications as a reference, who explains clearly in their letter why you should be considered for employment. Letters of recommendation are typically generic, and therefore suitable for any job

[12] e.g. Unofficial transcripts, attendance records, awards and recognitions, project portfolios.

you might apply for. You would not, for example, request multiple letters of recommendation be written by the same person, each one targeted toward a different job.

Beware anyone who offers to sign their name to a letter of recommendation you write for yourself. A letter of recommendation needs to be an honest account of your capabilities written by someone who cares enough to take the time, not a self-assessment made to look like someone else's attestation. If someone offers to sign a letter you write for yourself, decline the offer and find someone else who is willing[13] to invest the time in writing their own letter of recommendation for you. Make copies of any letters of recommendation so that you will not have to approach the letter-writer(s) to ask for more should you need them for additional job applications.

One final note on the subject of references: after obtaining each reference's permission and providing them with a copy of your résumé, *leave them alone*. Do not contact them later to ask whether or not they have been contacted by any employers. Do not ask them to divulge questions they were asked by the employer(s). Send them a thank-you card once you are hired if you wish, but meanwhile trust that each of them will represent you fairly and honestly, and that they will contact you if necessary.

[13] Think about this carefully for a moment. Why would you trust someone to represent you well if they are so lazy and/or unethical they won't even write you a short letter to help you get a job? If you need further reason to reject this unwise course of action, consider what will likely happen if the employer decides to contact the supposed author of that recommendation letter to clarify specifics. A reference will remember what they wrote, but probably won't remember what *you* wrote, and this will become painfully evident during that conversation.

5.3 Cover letter examples for recent graduates

Here is an example of a good cover letter for a recent graduate of an Instrumentation program, with no prior industrial experience, applying for a job in a cereal manufacturing facility:

```
4321 Main Street
Blue Falls, ID 83671
(123)-555-2121 doug_prosp@hotmail.com
July 14, 2017

Ms. Elaine Carter
Director of Human Resources
Soylent Organic Foods, LLC
8822 Midvale Road
Venada, ID 83675

Dear Ms. Carter,

Last week I read the posting on Indeed.com for an instrument technician at
Soylent Organic Foods.  This is my focus of study at Centerview Technical
College, which is detailed in my enclosed resume.  My experience working as a
line operator at Great Grains Breakfast Cookies has taught me some of the
unique aspects of food processing, which I am eager to explore at Soylent.

Food processing has interested me for many years, beginning with my love of
baking.  Centerview's Industrial Automation and Control Technology program
taught me the fundamentals of process control, with some of the coursework
applying directly to the food industry.  One such project was a PLC-controlled
bread-baking machine, which I designed, built, and diagnosed with teammates
for the purpose of automatically mixing, kneading, and baking loaves of bread.

You may reach me by telephone or by email, ideally between the hours of 3:00 PM
and 6:00 PM when I am between school and work.  Your time and attention is
greatly appreciated, and I look forward to the opportunity of being considered
for this position.  I will contact you in 7 to 10 days to follow through.

Sincerely,

(Signature)

Douglas C. Prospective

Enclosure
```

Let's review the good features of this cover letter:

- Note the proper business letter format: the writer's full address and contact information on top, followed by the recipient's name, title, and full address, followed by a professional salutation ("Dear . . ."). The letter ends with the word "Sincerely" followed by a hand-written signature and the writer's printed name. The word "Enclosure" reminds the reader of the résumé referenced in the body of the letter. If this letter were to be electronically communicated to the Human Resources department (e.g. email, fax) rather than printed on paper, the proper word at the end would be "Attachment" rather than "Enclosure".
- Note the perfect spelling and grammar throughout.
- Note how only two of the sentences begin with a first-person pronoun: "my" and "I" respectively.
- The **first paragraph** opens with a brief explanation of how the writer first learned of the open position and why they believe they are qualified for it.
- The **second paragraph** goes into more detail outlining the writer's interest in the position and how their personal and academic experiences are well-suited for it. If you have relevant details of your qualifications too lengthy to fit on your résumé, this is where you put them!
- The **third paragraph** expresses appreciation for the reader's attention, and provides details regarding future contact between the writer and the recipient.

Here is an example of a not-so-good cover letter for a recent graduate of an Instrumentation program, with no prior industrial experience, applying for a job at the same cereal manufacturing facility:

```
7324 Main Street
Blue Falls, ID 83671
(123)-555-3333

Director of Human Resources
Soylent Organic Foods, LLC
8822 Midvale Road
Venada, ID 83675

To Whom it May Concern,

I saw the Indeed.com posting for an instrament technician at Soylent Organic
Foods and I am very interested in working for you.  I study instrumentation
at Centerview Technical College.  I like to bake stuff and learn about
tech.

I am a very hard worker and fast learner.  I know I would do a great job for
you if you hired me.  I earned high grades in school and I studied really
hard.  In school I learned about pressure, temperature, level, flow,
analysers, control valves, PLCs, DCS, HART communicators, ethernet, serial
networks, valve positioners, PID, loop sheets, Fluke calibrators, circuits,
VFDs, pressure relief valves, boilers, transformers, multimeters, RTDs,
thermocouples, pressure gauges, wheatstone bridge, series and parallel,
oscilloscopes, function generators, NIST, autocad, vibration sensors,
manifolds, manometers, tube bending, soldering, terminal blocks, fuses,
resistors, etc.

Plz call me at 123-555-3333 as soon as you can because I want to interview
for this great position and I thank you for your time and attention because
I know you must be a really busy person with a ton of responsibilities and
you have lots of other people to interview to.  Have a great day!

Yours truly,

(Signature)

Samantha L. Prospective
```

Let's review this train wreck of a cover letter:

- The quality of writing is quite poor in general, with run-on sentences in addition to unusually short sentences.
- Note how many sentences begin with the first-person pronoun "I".
- Note the spelling errors: *instrament* instead of instrument, *to* instead of too (after the word "interview").
- Note the use of informal, non-business terms such as *Plz* instead of please, *ton*, *lots*, *tech*, and *stuff*.
- Note the self-assessment statements (e.g. "I am a very hard worker") which are inappropriate because they originate from a biased source (you).
- The list of topics learned in school is far too long, fairly random in terms of topic, and completely redundant to any well-written résumé.
- The casual tone of the letter is entirely inappropriate in business: e.g. "Yours truly" instead of "Sincerely" at the close, the overly-friendly "Have a great day!" at the end.
- Note how the letter is not addressed to anyone in particular. If at all possible, identify an appropriate *individual* at the company and address the letter to that person. If this is not possible, at least address the letter to the *title* of that person (e.g. "Dear Director of Human Resources,"). Never address your cover letter to an anonymous pronoun (e.g. "Whom", "Sir", "Madam", etc.).
- The letter does not end with a reminder of an enclosed or attached résumé. Remember, if you are sending the letter and résumé as printed (paper) copy, the cover letter should read "Enclosure" at the end; if sending electronically rather than by paper it should read "Attachment".

Unlike résumés which are very succinct summaries of educational and work experiences, a cover letter must actually be a *letter* written in such a way as to convey genuine interest on your part and an appropriate level of respect to the recipient and to the company at which you hope to eventually work. As mentioned previously in this tutorial, a well-written cover letter should sound good when read aloud. This letter clearly fails that test.

Many students find cover letters difficult to write because they are unaccustomed to writing in general. This is both sad and completely unnecessary. Our internet-connected world affords a great many opportunities to practice writing, and I would encourage everyone to treat every email message and every text posting on social media as an opportunity to practice a more formal and grammatically correct style of writing. *This is a skill born of practice*, so start today!

5.4 Job description examples

A *job description* is a formal declaration of basic responsibilities, required qualifications, and other information specific to a particular position of employment at a company. These vary considerably from employer to employer, but all contain some common information. In order to write your résumé and cover letter to target a particular job, you will need to reference the posted job description to identify skills and other qualifications necessary for consideration. Job descriptions also provide some of the information necessary for you to make an informed decision on whether or not you would even want to work in that capacity.

Perhaps the most misleading element of any job description within the field of industrial instrumentation is the section describing *required* qualifications. Unlike the job summary which is typically very accurate, the "required" qualifications are often more flexible than the job description might suggest. Contributing factors to this flexibility include the technical diversity of instrument technician jobs, the shortage of qualified applicants, and often a lack of clear understanding from the employer's perspective on what makes a person qualified[14]. At large companies where instrumentation is a well-understood field and where multiple technicians are already hired, this may not be so much of a problem, but at smaller companies where few technicians are employed and instrumentation duties are often blended with other maintenance duties, the company is more often than not willing to compromise on their "required" qualifications in order to get anyone who can do the job at all.

One of the most flexible qualification parameters is *work experience*. While some companies maintain a hard line on minimum work experience, most employers are willing to consider a talented applicant with less experience than what is stated in the job description. In fact, have lost count of the number of fresh graduates who have landed jobs with experience requirements such as "5 years minimum"!

Some qualifications, however, are much more rigid. Requirements for specific certifications such as state electrical licenses, security credentials, and licenses specific to the industry (e.g. operator licenses for water treatment, nuclear power plants) are non-negotiable for maintaining[15] employment.

The majority of job descriptions you read will likely bear no mention of pay. Some will simply say *DOE* (Depends On Experience), while others say nothing at all. This means you will need to decide whether or not to apply for the job based strictly on the duties and challenges it provides.

[14] I have had conversations with employers who list the possession of a Bachelor's degree a "necessary" qualification for their instrument technicians, and the reasoning usually goes something like this: they tried advertising for instrument technicians, and nobody they interviewed with a two-year degree was qualified enough, so won't four-year degree holders be better? The fact is that Bachelor's programs are predominantly focused *engineering* rather than hands-on technician work, and so it is the rare four-year engineering graduate who would do well as an instrument technician. This is precisely why I have found myself having these conversations to begin with: these employers got frustrated at not finding qualified people even after raising the academic bar on their required qualifications. One of the strange attitudes prevalent in American culture is that *more education makes a person more qualified for any job*, but I digress.

[15] However, some employers will be flexible on possession of said licenses or credentials upon *initial hire*. A good example of this is with electrical licenses, which may be waived for a specified period of time to allow the new employee to gain the experience necessary to qualify for that state license, after which they must maintain that license to remain employed. Electrical licenses are a prime example of this, because it is frankly difficult to find licensed electricians possessing a robust knowledge of instrumentation. As such, many instrument technicians get employed with the proviso that they obtain their state electrical license within a set time, their tasks during that probationary time apprenticeship-level duties not explicitly requiring the license.

Of course, compensation *is* important, but most employers don't want that being the sole criterion by which someone decides to apply and so they choose to omit it from their job descriptions.

One more note: do not be surprised to find job descriptions with spelling errors, grammatical errors, and other problems. While it may seem grossly unfair to have your résumé and cover letter scrutinized for grammatical correctness while applying for a job where the Human Resources department obviously didn't even bother to run spell-check on the document before posting, this is simply the way of the world. *Get used to it.*

Here is an example of a multi-page job description for an instrument/electrical technician working at a milk-processing plant:

```
Electrical/Instrumentation Technician
Amalgamated Milk Products - United States

DEPARTMENT: Engineering/Controls

REPORTS TO: Electrical/Instrumentation Supervisor

FLSA STATUS: Non-Exempt

SCHEDULE:

Day shift, subject to change according to business needs.  Must be available for on-
call and off-hours work due to business needs.  Must be available for regular
standby assignments including a rotating on-call after-hours incident response schedule.

JOB SUMMARY:

The Electrical/Instrumentation Technician provides support for the production
manufacturing facility.  He or she will be knowledgeable on all production lines and
equipment and will have the ability to troubleshoot and repair equipment throughout
the facility.  The technician is responsible for completing work orders, carrying out
preventative maintenance schedules, and installing of new equipment.  In addition they
will be expected to troubleshoot process system equipment to support production,
future projects, and/or process improvements.  Teamwork and coordination is essential
to this position's success.  The Electrical/Instrumentation Technician shall be able
to make decisions pertaining to the plant electrical system and instrumentation systems
with minimal supervision.

ESSENTIAL FUNCTIONS, DUTIES AND PERFORMANCE RESPONSIBILITIES:

* Provides technical expertise to plant personnel during equipment problems, repair,
troubleshooting and during root cause investigations.
* Sets up, calibrates, tests, measures and repairs all types of electrical controls,
instruments, and electronic components.
* Collects equipment operation history and data to facilitate reliability improvements.
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* Troubleshoots and repairs malfunctions and helps document failure analysis.
* Performs daily PM's of equipment and instrument calibrations.
* Plans and performs work requiring a thorough knowledge of electrical/electronic and
mechanical theories and principles, writing specifications, local and national
electrical codes, properties of various materials, and principles of operation and
application of electronic equipment.
* Is a proactive member of the team and as such identifies, repairs, and improves
processes with an attitude toward preventing down-time.
* Monitors controls and electrical equipment to ensure effective and efficient service.
* Ensures Preventative Maintenance procedures are executed in a timely manner and in
accordance with SOP and SSOP.
* Dismantles functional systems and tests individual components.
* Sets up and operate tools used to diagnose and repair equipment.
* Installs electrical conduits using a hand, mechanical, or hydraulic bender.
* Starts up systems, observes operation, reads and calibrates gauges and instruments,
and adjusts mechanisms such as valves, controllers, and pumps to control level of
fluid pressure and temperature in plant systems.
* Keeps maintenance shop and assigned areas neat, clean, and organized.
* Configures HART/smart devices using a HART communicator.
* Troubleshoots and configures VFD's over Ethernet and DeviceNet networks.
* Works well with the Maintenance department to help solidify electrical repairs and
assist with projects.
* Demonstrates sound work ethics.
* Supports and encourages greater employee teamwork.
* Knows, understands, and follows OSHA and state Safety Regulations.
* Follows LOTO policies and NFPA 70E.
* Communicates safety issues to mangers and Safety department.

JOB SPECIFICATION/QUALIFICATIONS:

Education:

* Required: High School diploma or GED
* Required: Oregon State Journeyman Electrical License
* Preferred: Associate Degree (AA) in Instrumentation and/or strong instrumentation
background with the ability to troubleshoot instrument/control problems from the
field to the DCS.

Experience:

* Required: Minimum one year Instrumentation experience
* Required: Minimum one year in food and beverage plant experience.

Knowledge:

* Extensive knowledge of industrial 480 Volt equipment including but not limited to:
Motor Contactors, Motor Control Centers, Variable Frequency Drives, Heat Tracing,
Motors, Fuses, Disconnects, Circuit Breakers, and Power Distribution Systems.
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* Working knowledge of Alternating Current (AC), Direct Current (DC) voltage systems
and uninterruptible Power Systems (UPS).
* Working knowledge of low/medium/high voltage breakers and power distribution
systems.

Skills:

* Demonstrated ability to effectively troubleshoot and use problem solving skills.
* Interact effectively and influentially with a broad range of personnel (craftsman,
technicians, vendors, engineers and management).
* Ability to read and comprehend written project and equipment specifications,
manufacturer's recommendations, detailed mechanical assembly and component drawings,
Piping and Instrument Diagrams.
* Sound communication skills, both verbal and written.
* Demonstrated ability to ensure all documentation is timely, accurate, and complete.
* Must have an established work record that depicts that he or she is reliable and
adds value to an organization through service and acceptance of responsibility.
* Effectively interacts with individuals, teams, supervisor, management.
* Effective decision making skills, critical thinking, and problem solving skills.
* Accuracy and attention to details in daily activities.
* Highly organized, with the ability to adapt quickly to changing priorities.
* Good interpersonal skills.
* Effective prioritizing and time management skills.
* Able to work in teams effectively and encourage a positive work environment.
* Demonstrated ability to learn new concepts, accept and embrace change, and be an
active member of our team.

Physical Requirements:

* Occasional ascending and/or descending of ladders and stairs using feet and legs
and/or hands and arms on a regular basis.  Body agility is emphasized.
* Walking: Moving about on foot to accomplish tasks, particularly for long distances
on a regular basis.
* Repetitive motions: Substantial movements (motions) of the wrists, hands, and/or
fingers.
* Standing: Particularly for sustained periods of time on concrete.
* Stooping: Bending body downward and forward by bending spine at the waist on a
regular basis
* Reaching: Extending hands and arms in any direction.
* Pushing: Using upper extremities to press against objects with steady force in
order to thrust forward, downward or outward.
* Pulling: Using upper extremities to exert force in order to draw, drag, haul or
tug objects in a sustained motion.
* Lifting: Able to lift up to 40 pounds on a regular basis.
* Kneeling: Bending legs at knee to come to a rest on knee or knees occasionally.
* Crouching: Bending the body downward and forward by bending leg and spine.
* Talking: Expressing ideas by means of the spoken word.  Includes activities in
which they must convey detailed or important spoken instructions to other workers
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accurately, loudly, and/or quickly.
* Subject to noise levels of at least 92 dB.

Machine/Software:

* Office machines (e.g. personal computer, copy machine, fax machine, calculator,
and telephone).
* Good working knowledge of Microsoft Office (Excel, Word).


COMPENSATION AND BENEFITS:

* Pay DOE
* Excellent benefit package available: medical, dental, vision, disability, life
insurance, FSA, vacation, PTO, holiday pay, 401k subject to applicable eligibility
and waiting periods.

To apply for this position please visit our website at
http://www.amalgamatedmilkproducts.com and click the JOIN OUR STAFF link in the
top right hand corner.

Job Type: Full-time
```

Let's review some of the salient points of this job description, shall we?

- First, note the *FLSA* status. This refers to the Fair Labor Standards Act of 1938, which among other things defines whether or not an employee is eligible for overtime pay. A "non-exempt" employee is entitled to overtime pay as stipulated in the FLSA if they exceed their normal working hours, while an "exempt" employee does not enjoy that protection afforded by the FLSA. We can see in this case that the job is non-exempt, which means any overtime worked must be accompanied by overtime pay (at a rate equal to 150% the normal hourly wage, which is often called "time-and-a-half" pay).
- Note some of the other acronyms found in this job description: *LOTO*, *SOP*, *FSA*, *PTO*, *SSOP*, etc. It is incumbent upon you to research what these mean so that you may fully understand what the job description is saying. General internet searches are often the most useful way to define acronyms, although you will likely have to apply educated guessing in order to determine which definition best fits, as many acronyms have multiple uses. Some of these terms are common throughout a range of industries (e.g. "LOTO" means Lock-Out, Tag-Out; "SOP" means Standard Operating Procedure; "FSA" means Flexible Spending Account which may be used to for health care expenses) while other are more specialized (e.g. "SSOP" means Sanitation Standard Operating Procedure, which is specific to food-processing industries where special sanitation protocols must be followed to ensure safety of the product).
- This job is fairly comprehensive in terms of work scope. Not only is the technician responsible for all maintenance of electrical equipment (including voltages above and beyond 480 Volts

which is what "medium" and "high" voltage refers to!) and all instrumentation systems (from field instruments to the Distributed Control System), but they are also expected to be able to operate the equipment as well ("Starts up systems . . .") as part of their job. Although it's unlikely such a person will be tasked with daily production, they will still need to be able to start and stop equipment in the absence of a qualified operator to assist.

- The work experience threshold is quite modest, asking for only 1 year of experience in Instrumentation and only 1 year experience with food and beverage operations. This bodes well for fresh graduates, who may be able to negotiate based on a solid track record in school (managing complex projects) and/or a solid work record in some other job.

- Communication with technical and non-technical personnel alike is clearly important to this job, and they know it. This means they will scrutinize you on your ability to clearly convey thoughts, expectations, and ideas. If your résumé, cover letter, or interview betrays inaccuracy, confusion, or lack of clarity, you will have a hard time convincing them to hire you.

- This job comes with definite physical performance expectations. Chronic medical problems or injuries preventing you from performing all the physical tasks described may be problematic. Chances are you will likely have to pass a physical examination and a simple agility test as part of the screening process for this job.

- Expect that the interviewer(s) will demand concrete examples of your experience solving problems, making important decisions, handling interpersonal stresses, and maintaining deadlines. While this is fairly standard for all technical job interviews, you can tell it will almost certainly be an emphasis here based on how often the job description identifies these and related skills.

Next up is a job description that is *not* appropriate for an instrument technician:

```
Standard Oil -- I&E Reliability Engineer -- Otisville Refinery

FLSA STATUS: Exempt

DESCRIPTION:

The I&E Reliability Engineer provides technical support for routine maintenance
of the refinery's instrumentation and electrical assets while improving these areas.
This position requires a proven problem solver and equipment owner serving as the
site's leading technical resource for electrical infrastructure.

RESPONSIBILITIES:

* Participating and promoting all aspects of refinery safety programs.
* Visibly demonstrating commitment to workplace safety and the health of employees
and contractors through personal engagement and sound decisions.
* Maintaining the site's Electrical Safety Program and ensuring on-going compliance
with NFPA 70E and regulatory codes.
* Providing routine maintenance engineering and troubleshooting support for
instrumentation, analyzers, and electrical equipment.
* Overseeing the instrumentation asset base which includes field measurement sensors,
transmitters, analyzers, Honeywell Experion DCS, and control valves.
* Overseeing the electrical asset base which includes medium-voltage transformers,
distribution lines, circuit breakers, electrical motors up to 5,000 HP, disconnects,
power factor correction capacitors, batteries, generators, lighting, heat tracing,
motor control centers (MCCs), and protective relays.
* Creating and evaluating preventive maintenance plans, procedures, and training
programs.
* Designing, recommending, and implementing new equipment solutions where justified.
* Evaluating and recommending improvements to critical spares inventory and storage
solutions.
* Ensuring electrical design specifications, construction, and testing of electrical
equipment are in compliance with electrical codes, regulations, standards, and
company-wide good engineering practices.
* Maintaining and reviewing electrical power coordination for the refinery including
load flow, voltage drop, relay settings, motor starting, arc flash, and equipment
duty using software models including support for expansions.
* Ensuring single line drawings and electrical area classifications are up to date.
* Participating in knowledge share with other sites within the company by serving as
the site's core member in both the electrical and instrumentation networks, and
serve as a primary contact with the electrical utility provider.
* Effectively communicate and engage with other functional groups at all levels from
craftpersons and operators to refinery management.
* Initiate and evaluate Management of Change (MOC) process and also lead and assist
with incident investigations.
```

```
BASIC QUALIFICATIONS:

* Legally authorized to work in the USA.
* Bachelor's degree in electrical engineering (BSEE) from an IBET-accredited program.
* 2 or more years of electrical power experience within an industrial environment.
* Intermediate level of working knowledge with National Electric Code and NFPA 70E.
* Must currently hold or be able to qualify to receive a Transportation Worker
Identification Credential (TWIC) card.  Note, information regarding TWIC
qualification standards may be found at www.tsa.gov/whatwedo/layers/twic/index.shtm
* Ability and willingness to perform/comply, with or without a reasonable
accommodation, with the following: climbing, standing, crawling in confined space
areas; maneuver through process areas containing pumps, towers, compressors,
and piping systems; wear refinery required Personal Protective Equipment (PPE);
work in outside weather conditions including cold and heat; maintain shaven face
daily so that a respirator/face mask can seal properly; be available for on-call
support 24/7/365.
* Possession of a current state Driver's License.

PREFERRED QUALIFICATIONS:

* Professional Engineering (PE) license.
* Maintenance experience with medium voltage power distribution systems and
utilization equipment.
* SEL and GE digital protective relay configuration.
* Ability to write reports, business correspondence, and procedure manuals.
* Strong verbal, written, and interpersonal communication skills.
* Demonstrates strong problem-solving skills.
* Accepts ownership, is accountable and delivers on commitments.
* Strong technical knowledge and ability to apply practical solutions in the field.
* Ability to work effectively with standard computer applications involving word
processing, spreadsheets, and relational databases.
* Ability to work extended shifts and respond to after-hours call outs.
* Experience working with both instrumentation and electrical equipment.

In order to be considered for this position you must complete the entire application
process, which includes answering all pre-screening questions and providing your
eSignature on or before the requisition closing date of October 6, 2017.

Candidates for regular US positions must be a US citizen or national, or an alien
admitted as permanent resident, refugee, asylee or temporary resident under
8 U.S.C. 1160(a) or 1255(a)(1).  Individuals with temporary visas such as E, F-1,
H-1, H-2, L, B, J, or TN or who need sponsorship for work authorization now or in
the future, are not eligible for hire.

Standard Oil is an EEO and Affirmative Action Employer of Females/Minorities/
Veterans/Individuals with Disabilities.

Requisition ID: 84331
```

```
Department: Otisville Refinery

Location: United States

Job Field: Engineering
```

As previously mentioned, this job description does *not* fit that of an instrument technician. I show it in order to help distinguish instrument engineering work from instrument technician work, which unfortunately tends to be blurred in some industries. Let's see why this particular job description fits engineering better than technician work:

- Perhaps the clearest clue that this is a bona fide engineering position and not a technician position is the basic qualification of a Bachelor's degree and the preferred qualification of a Professional Engineering license.
- Furthermore, the job description never actually states that the person will perform physical work with the equipment. The actual verbs used to describe the engineers work include *overseeing*, *designing*, *evaluating*, and *recommending* which are all more abstract than technician-centric verbs such as *calibrating*, *rebuilding*, *configuring*, and *installing*.
- Certain job responsibilities listed in this job description essentially *establish safety practices* at the worksite. An example of this is ensuring *electrical area classifications* are kept up to date, which refers to hazardous areas (Classes/Divisions or Zones) used to define the potential for fire or explosion as the result of an electrical spark. An instrument/electrical technician may need to ensure the correct (certified) equipment gets installed in these areas, but would never take action to *redefine* the boundaries of those areas within the plant. Another example is maintaining the site's Electrical Safety Program to ensure compliance with various codes. A technician is of course required to *follow* the site's safety protocols, but would never be responsible for single-handedly altering them as an engineer would have to do if non-compliance were determined.
- Certain job responsibilities imply a level of responsibility foreign to a technician's role. An example of this is serving as the site's *primary contact* with the local electrical utility.

It is interesting to note that many of the responsibilities listed in this instrument engineer job description overlap the responsibilities of many instrument technicians, so blurred are these categories in industry. These include: protective relay configuration, report writing, computer application use, accessing confined spaces and wearing PPE, working knowledge of NEC and NFPA 70E, troubleshooting, creating and evaluating procedures, and maintaining accurate documentation. The lesson here is that when evaluating a job description for appropriateness to your capacity as an instrument technician, it is not enough to discover positive matches within the job description to your knowledge and skill set; you must also be looking for *clear and unambiguous mis-matches*[16] where you would most definitely *not* be qualified for the job.

[16] One of the most difficult mis-match to identify is the requirement for a four-year Bachelor's degree. One

The following job description is one more suited to an instrument technician, although it carries the title of Engineer:

```
JOB SUMMARY:

Voltron Industries is a dynamic company in the field of health, agricultural, and
performance chemicals.  Our culture is built on mutual trust and respect for all
employees so that we can focus on providing the best products and solutions to our
customers.

Voltron Industries is currently seeking an Automation Engineer to work out of our
Washburn manufacturing facility.  This position is responsible for troubleshooting,
calibration, upgrade, and repair of sensors and control systems regulating flow,
pressure, temperature and level.  This position is also responsible for the
installation and maintenance of all plant electrical equipment and wiring systems.

RESPONSIBILITIES:

* Assist Engineering Manager with project work to include PLC program development,
assembly and maintenance.
* Configure, calibrate, install, and troubleshoot the following instrumentation:
Level, Pressure, Temperature, Flow, Switches, Relays, Solenoids, and Valve
positioners from various manufactures.
* Diagnose problems in 480 volt three-phase motor control circuits.
* Comply with Lockout-Tagout (LOTO) Program and all relevant safety codes.

QUALIFICATIONS:

* Degree in Electronics, Instrumentation, Electrical Engineering Technology or a
related field.
* Prefer candidates with 3+ years field experience with electrical and mechanical
controls.
* Must be able to read, follow, and markup electrical drawings and P&ID's.
* Must be experienced in using a HART Communicator and Fluke DPC calibrator.
* Expected to work with Engineering in PLC development, assembly and maintenance.
* Understanding of Allen Bradley Logix5000 PLC ladder logic programming.
* Experience with Toshiba VFDs is a plus.
```

would think this would be an immediate disqualifier for a graduate of a two-year Associate's degree program in Instrumentation, but I have seen enough two-year Instrumentation graduates obtain jobs listed for "four-year" degree holders to give me pause on this point. Now, it is impossible to obtain a state engineering license (PE) with only a two-year degree, but if the possession of that license is not an absolute requirement, some companies are willing to let a two-year graduate do engineering work.

Clues indicating the suitability of this job to an instrument technician rather than to an engineer include the following:

- Diverse degrees accepted for the job (Electronics, Instrumentation, *or* Electrical Engineering Technology[17])
- The job tasks are almost all hands-on activities: *troubleshooting*, *calibration*, *repair*, etc.
- Expectations are that this person will *work with* Engineering suggests there is a separate Engineering department at this facility populated by degreed (and perhaps licensed) engineers.

[17] The inclusion of Electrical Engineering *Technology* is a strong indication that they are not looking for a full engineer. These "technology" degrees are considered insufficient for engaging in the Professional Engineering license process (FE and PE exams), and anyone unqualified to take the FE/PE exams cannot be considered an "engineer" in the fullest sense of the word.

Chapter 6

Interviews and the screening process

Let's begin with an honest admission: *interviews are about as much fun as dental surgery.* The reasons for this fact are not difficult to grasp. Few circumstances in life subject you to more scrutiny at the hands of complete strangers than a job interview. Given the typical number of applicants to any one open position, your odds of landing the job based on head-count alone are not good either. Add to this unsavory mix the novelty of the interview process and you have a situation no sane person looks forward to.

There is reason, however, to take heart. Like dental surgery, job interviews are experiences most people in life have not only survived, but have actually managed to emerge in a better condition than when they entered.

Interview questions take two general forms: *technical* and *behavioral*. Technical questions focus on all the trade-specific knowledge and skills you should have learned in college (or from self-study, or from previous employment). Behavioral questions focus on general "soft skills" such as teamwork, time and resource management, organization, work ethic, and attitude. The balance between technical versus behavioral questions in any interview seems to be random – some employers exclusively ask behavioral questions, others are almost entirely technical, but most are a mix.

Like any performance art, successful interviewing is a test of composure and stress-management skills. As an performer knows, dedicated *practice* is the key to gaining confidence. Fortunately for job-seekers, a variety of resources exists to help prepare for interviews. Employment agencies often offer *mock interviews* for those desiring more confidence during interviews. If you are enrolled in a school preparing you for employment, the Career Services department of your school more likely than not offers the same. Another resource is to simply have your friends and/or family stage a fake interview for you[1].

[1] The last time I applied for a job, I had two good friends do this for me. Even though their questions were not technical, they were still able to query me with challenging behavioral questions and also give valuable feedback on my performance. One such detail they noted was that I had a bad tendency to fidget with my wedding ring as I answered questions. Thanks to their help, I successfully avoided this habit during my real interview!

Aside from practice, another helpful strategy is to enter your interview(s) fully *prepared* in terms of what to say. You should carefully study common behavioral questions asked during interviews, as well as know your résumé and cover letter extremely well. You should always bring extra copies of your résumé and cover letter just in case any people on the interview panel lack copies of their own, plus your reference page and any other supporting documentation such as letters of recommendation and project portfolios.

6.1 Sample technical questions

Here is a list of sample technical questions related to industrial instrumentation. Note that many of these questions are purposefully vague, so that they may support multiple correct answers depending on the context in which they are interpreted. This is by design, as the interviewer(s) want to know what your *assumptions* are as much as they want to test your *knowledge*[2]:

- Describe the purpose and steps involved in rebuilding a control valve.
- Explain what "zero" and "span" refer to in an instrument.
- Explain what *HART* is.
- Explain what *FOUNDATION Fieldbus* is.
- Explain what *Modbus* is.
- Explain what *Profibus* is.
- Explain what *OPC* is.
- Describe the steps necessary to set up an oscilloscope prior to using it to take a circuit measurement.
- Explain what *lockout-tagout* means, and why it is important.
- How do you switch the direction of a three-phase electric motor, and why does that work?
- What is a *VFD*, and what purpose does it serve?
- Describe how you would test a *transformer* for internal faults.
- Describe how you would test a *diode* for proper operation.
- Describe how you would test a *transistor* for proper operation.
- Describe how you would test an *SCR* for proper operation.
- Explain the purpose of an *overload heater* in a motor control circuit.
- Identify multiple uses for a *differential pressure* sensor.
- Identify multiple types of mechanical pressure gauge elements.
- Identify multiple types of electronic pressure sensor.
- Identify multiple technologies useful for measuring liquid level.
- Identify multiple technologies useful for measuring temperature.

[2] In all cases it is recommended to answer the questions as thoroughly as you can. Giving too short of an answer will only serve to force the interviewer to ask further questions, which has the undesirable effect of annoying the interviewer. The last thing you want to do is to annoy your interviewer!

- Identify multiple technologies useful for measuring liquid flow.
- Identify multiple technologies useful for measuring gas concentrations.
- Identify multiple technologies for control valve bodies.
- Identify multiple technologies for control valve actuators.
- Define *accuracy*.
- Explain what *arc flash* means, and why it is dangerous.
- Define *hysteresis*.
- Describe the steps you would take to measure the amount of *hysteresis* in a control valve.
- What is the difference between a PLC and a DCS? Where might you use each type of system?
- What is a flapper/nozzle assembly, and what does it do?
- Explain the difference between *common-mode* and *differential* voltage.
- Describe the effects of electric *shock*, and appropriate first-aid for it.
- Explain what *Management of Change* (MOC) refers to in industry, and why it is so important.
- How would you test the gain of an amplifier?
- How do you ensure a calibration is NIST-*traceable*?
- Why do we typically check an instrument's calibration in two directions, going both up and down its measurement range?
- Sketch a diagram for a *full-wave bridge rectifier* circuit.
- Design a voltage divider with a ratio of _____.
- Explain what *Proportional* action does in a PID controller.
- Explain what *Integral* or *Reset* action does in a PID controller.
- Explain what *Derivative* or *Rate* action does in a PID controller.
- Explain why it is generally bad to connect an ammeter in parallel with an electrical source.
- Explain why it is generally bad to connect a voltmeter in series with an electrical source.
- Identify the wire colors for a type ____ thermocouple cable.
- Describe how to properly terminate a wire prior to inserting it into a terminal.
- Describe how to properly terminate a tube to a compression-style tube fitting.
- Describe how to properly assemble NPT pipe fittings.

- Describe how to safely test a tube or pipe fitting for leaks.
- Describe the Ziegler-Nichols method for tuning a PID controller.
- Explain the purpose of a *thermowell*.
- Describe the advantages and disadvantages of 2-wire versus 3-wire versus 4-wire RTD circuits.
- Identify multiple reasons that could cause a PID-controlled loop to oscillate.
- Identify multiple reasons that could cause a PID-controlled loop to fail to achieve setpoint.
- Explain why we sometimes use *redundant* transmitters in a control system.
- Identify multiple reasons why two devices connected together on an Ethernet network might fail to communicate with each other.
- Describe the diagnostic steps you would take to troubleshoot _____.
- Explain why we always use *flux* when performing electrical soldering.
- Explain how a 4-wire transmitter is wired to the input of an indicator or controller.
- Explain how a 2-wire (loop-powered) transmitter is wired to the input of an indicator or controller.
- Describe the purpose of obtaining a *work permit* prior to commencing work in a hazardous area of the facility.
- Examine this schematic diagram and identify all errors you see in it.
- Examine this instrument and identify as many components of it that you can.
- Examine this schematic diagram and predict the amount of voltage/current you would expect to measure *here*.
- Examine this gauge face and identify what it reads.
- Convert the decimal number _____ into binary format.
- Describe the steps involved with using a *deadweight tester*.
- Examine this PLC program and identify what will happen given the following input switch states.
- Explain how to use a multimeter to locate a short between two wires of a multi-conductor cable.
- Explain how to use a multimeter to locate a open along a wire of a multi-conductor cable.

It is important to realize that you will most likely be asked some technical questions beyond your ability to answer, at least while sitting in the interview room. The interviewers' job is to push you to the limits of your technical knowledge, and it is your job during an interview to handle this inquisition with grace. Just because you cannot answer *all* their questions doesn't necessarily mean you won't get the job! If you find yourself stumped by a technical question, a good way to respond is to tell them you don't know the answer (yet), but then go on to explain how you would go about answering it. Hint: doing a Google[3] search is not the answer they want to hear!

[3]Internet search engines are very useful tools, but widely over-used. Doing this as a first, or worse yet *only* step is a lazy person's answer. It is better to refer to a specific technical reference you know is related to the question at hand, such as one of your textbooks, or to a user's manual, than to trust an internet search engine for the information you need.

6.2 Sample behavioral questions

Here is a list of sample behavioral questions you may be asked during an interview for an instrument technician position, but are actually generic to most jobs. Perhaps the most important element of your response to most of these questions is that it must refer to a real event in your life, not an hypothetical answer[4]. This is true even if it sounds like the question is hypothetical! In other words, the interviewer wants to *know* how you actually behave, not how you *think* you would behave, or how you would *like* to behave. Any relevant scenario from your life is permitted – it does not have to be an event from the workplace if you have never encountered such a thing on the job:

- Identify specific strengths you would bring to this job.
- Describe a situation where you changed your mind about something very important.
- How do you handle disagreements with colleagues?
- What do you do when things are slow at work?
- What is your approach to managing conflict between people?
- Suppose you needed to research information needed for completing a job. What resources, besides an internet search engine, would you consult?
- Tell me about a situation where you made a big mistake, and what you did afterward.
- What would you do if you became aware of a co-worker stealing from the company?
- Describe how you are able to tell when a job you've completed is well-done.
- What is your experience working in teams?
- Describe your favorite ways to learn new information or new skills.
- Explain how you are able to effectively manage long-term goals.
- Describe your ideal of a workplace leader.
- How do you cope with a co-worker who is under-performing in his or her job?
- Identify the types of people you find difficult to work with, and explain why.
- Identify the types of people you find easy to work with, and explain why.
- Have you ever had to complete an important task without leadership from others to guide you?
- Describe a situation where the scope of a project you were involved with changed significantly over time, why that was, and how you handled that change.

[4]There are some questions which are obviously hypothetical. The question "How do you see your role as an instrument technician fitting into the larger vision of the company?", for example, requires an hypothetical answer because you do not yet work as an instrument technician at that company!

- How do you identify and maintain priorities?
- Describe your typical schedule and study habits during school.
- What do you expect to achieve during your first 30 days of working here?
- Describe how your contributions at your last job improved the business from what it was before you were hired there.
- Where has teamwork proven most effective on the job? What factor(s) led to this happening?
- Describe a project initiated and managed by you. Were others involved? If so, how many, and what were their roles in completing the project?
- Have you ever seen a team become ineffective? What factor(s) led to this happening?
- Have you ever been given an impossible task? If so, what was that task and how did you handle it?
- Have you ever had to make an unpopular decision on the job? What was it, and how was that tension resolved (if at all)?
- Describe your ideal for professional development.
- Where do you see your career heading in 5 to 10 years?
- How do you manage stress on the job?
- Describe an incident where a plan of yours failed, and explain how you were able to recover from that failure.
- What inspires you to do your very best work?
- Describe how you would proceed to write a Standard Operating Procedure (SOP) for testing an instrumentation system.
- Have you ever needed to persuade a co-worker to do something necessary that they didn't want to do? How were you able to accomplish that?
- Describe a work situation in which you felt uncomfortable.
- Have you ever held a position of authority over others?
- Describe a condition where extra work is necessary to truly complete a job.
- How much follow-up documentation would you define as being "a lot" to do upon completion of a task?
- Have you ever had to be the bearer of unpleasant news on the job? What was the news, and how were you able to effectively deliver the news?
- Describe a situation where you were proven wrong. What was the topic, and how did you handle this?

- What are some of the most important things you have learned through work?
- Identify information that you would consider *privileged* or *confidential* on the job.
- How do you define *respect* on the job?
- Is there a time you ever disagreed with your immediate supervisor? What was that disagreement about, and how did you handle it?
- Describe some of the challenges faced when managing purchases and expenses on the job.
- Describe what you enjoyed least about your previous job.
- Describe what you enjoyed least about school.
- How do you verify that someone has clearly understood instructions you have given to them?
- Describe a "healthy" workplace culture.
- Identify a workplace situation in which negotiation would be considered appropriate.
- Identify a workplace situation in which negotiation would be considered inappropriate.
- Suppose you need to give instructions to an adult on how to use a telephone, when that person has never seen or heard of a telephone in all their life. What would you say to them?
- Describe a situation where miscommunication led to problems on the job. What, specifically, could have been done differently to avoid the problem?
- Have either your words or intentions ever been misunderstood on the job? If you could go back in time and change what you said or did, what would you do differently?
- Describe a situation where you made an extraordinary contribution on a job.
- What do you consider to be your greatest accomplishment?
- Describe a situation where you helped to resolve an interpersonal conflict. How did you accomplish this feat?
- How comfortable do you feel presenting in front of large groups?
- Describe a situation where workplace politics were a major factor.
- Explain how to coordinate multiple busy peoples' schedules to be able to work together.
- Suppose you need to explain something complex about instrumentation to a non-specialist. How do you communicate this information to someone unfamiliar with the terms and principles? How do you ensure they have understood what you told them?
- If there was one thing you could change about your last job, what would that be, and why?
- Have you ever been asked to do something on the job you believed was unsafe? Describe how you responded to that request.

- Have you ever been asked to do something on the job you believed was unethical? Describe how you responded to that request.
- How do you see your role as an instrument technician fitting into the larger vision of the company?
- What is your greatest weakness?[5]
- Have you ever been convicted of a crime?

A useful model for responding to questions of how you have handled actual challenges is called the *STAR* method, and it consists of explaining the following four things: the *Situation* requiring attention, the general *Task* you needed to complete, the specific *Action* you took in completing this task, and the *Result* of all your efforts. This should not be too formulaic in your responses, but it is important to address all those points with each of your answers.

Here is an example of an inexperienced graduate might use the STAR method to answer a typical behavioral question related to work, even though they have no actual work experience: *How do you manage stress on the job?*

> "I'll relate an experience managing stress at school, because I don't yet have any job experience. Six months ago I was assigned a very challenging project: programming a PLC to count the number of objects passing by on two different conveyor belts, and to control the speed of both belts so that their rate of objects delivered per minute was the same. At that same time I came down with a bad cold and was having trouble sleeping because I was so congested. This combination stressed me out really bad. I knew this project was important, and that I needed to get it done by the deadline even though I was sleep-deprived. In addition to taking a decongestant to help with my sleep, I found ways to take short naps between classes, and I also cut out television from my life to give me more time to work on the PLC programming problem. I also found comfort by talking with close friends who had gone through similar stressful experiences when they were in college. At the end, I was able to get the rest I needed as well as finish the project in time. To be honest, I only earned a 'B' grade on that project because there were some documentation details I ran out of time to complete, but I feel very good about being able to manage the stress of that time."

Note the four elements of STAR present in this answer:

1. **Situation:** Challenging school project plus a bad cold leading to stress
2. **Task:** Getting the work done, getting more sleep
3. **Action:** Take medicine and daytime naps, cut out television from life, talk with friends
4. **Result:** Project completed, less stress!

[5] Despite this being a commonly asked question during job interviews, I have heard some professionals debate whether or not this is truly beneficial to ask. Given the rather obvious fact that most people feel extremely uncomfortable revealing their most significant flaw to complete strangers, this question seems useful only if your intention is to determine how well the applicant is able to lie. First, remember that the question deals with *work* and not your personal life – you are never under any obligation during an interview to reveal private information. Choose something you have found to be a significant challenge on the job (or in school, if you have no prior work experience) and describe that challenge, being sure to follow up with effective strategies you have applied to overcome that problem. My personal favorite (sarcastic) response to this question? *My greatest weakness is impatience with foolish questions!* Feel free to say this, of course, only if you don't care about getting the job!

6.3 Inappropriate and/or illegal questions

Some types of questions should *never* be asked by interviewers. These include:

- Any question of an explicitly personal nature, unrelated to work. These include questions related to protected classes among others:

  Race or Ethnicity

  National origin

  Religion

  Medical condition or disability[6]

  Gender

  Sexual orientation or habits

  Marital status

  Pregnancy

- Questions about specific[7] criminal convictions.
- Your age
- Your weight
- Questions about your friends or family
- Questions about controlled substance use (whether legal or illegal)
- Questions about why you left (or are leaving) your previous job

Although it is unlikely you will encounter any of these forbidden questions, it is good to prepare yourself anyway to handle this with professionalism. If you are very confident the question is illegal to ask or is wildly inappropriate[8], you may simply reply that you don't believe that question is

[6] It is reasonable to ask the applicant if any accommodations will be required for them to perform the job, and it is appropriate for an employer to have you undergo a physical examination as well as a physical fitness test prior to offering employment.

[7] It should be noted that general questions regarding criminal status are permitted, and that background checks will likely reveal any such status.

[8] I have been blessed with a number of inappropriate and/or awkward situations during job interviews. During one interview, I was taken out to lunch where the interviewer did nothing but watch me as I ate. During another interview, I was flatly insulted by the interviewer who told me I had wasted my time enrolling at a technical college when I should have joined the Navy. During another interview, I was asked to analyze a simple RC (resistor-capacitor) circuit and was "corrected" by one of the interviewers whose suggestion to test that circuit would have resulted in capacitor exploding. At the start of yet another interview I found myself entering the interview room with a group of men dressed in dirty work clothes starting at me slack-jawed for having dressed in business casual attire. This same interview dwelt largely on thermocouple applications, with the men asking me repeatedly to describe any *real-world* work experience I had with thermocouples, and me replying every time that I was still a student and had not yet worked at a facility using thermocouples, but that I was ready and willing to learn. Please note that this interview was set up by my instructor at the technical school at least four months in advance of graduation, because he specifically recommended me to the employer. Needless to say, I didn't get that job, nor did I want it by the end of the interview. On a final note, I wrecked my car on the return trip when I hit black ice in the interstate and flipped the car in the median – just the "cherry on top" I needed after that interview!

relevant to the job. However, as you might guess there are many "grey areas" here where one version of a question is considered illegal yet another is considered appropriate. One example is criminal conviction: it is flatly illegal for an interviewer to ask you if you have ever been arrested for drunk driving, but it is permissible for the interviewer to ask whether you have ever been convicted of a crime. A good strategy to employ if you are ever faced with an interview question you *think* might be inappropriate but you're not sure, is to answer the spirit of the question but not the letter of the question. For example, if you are a young-looking adult and someone asks you your age, you may reply that you are a "legal adult" rather than reveal your chronological age.

Furthermore, sometimes a questions that would be considered inappropriate for most job interviews is relevant for the particular job you're seeking. These are referred to as *BFOQ*s or *Bona Fide Occupational Qualifications*. While these are uncommon for instrument technicians, they include examples such as age for careers such as working for the FBI as a Special Agent[9].

6.4 Disclosure

A question I often receive from students preparing to apply and interview for jobs is the degree to which they should reveal details of certain misdeeds, especially legal troubles in their past. You will note, for example, that it is illegal for an employer to ask a prospective employee about a *specific* criminal conviction, but that does not mean they cannot ask a *general* question about a person's criminal history. A significant number of students I've met have some incident in their past where they ran afoul of the law, usually some time during their younger and foolish years, and they are worried this may cause problems for them as they attempt to start a career in Instrumentation.

There is no easy answer to this question than to simply say *"Be honest"*. However, honesty and disclosure are not the same thing. To answer honestly is to give a factual answer to a direct question. Disclosure, on the other hand, represents a *volunteering* of information. An interview is not the time or place to be volunteering information that could damage your prospects of getting that job, but it is absolutely the time and place to answer all direct (and legal) questions with full accuracy.

If the employer in question is going to run a background check after the interview and prior to offering any position (as *most* do in this industry), it is wise to prepare yourself for answering more detailed questions about the result of that background check.

[9] At the time of this writing (2017) the FBI still maintains strict limits on age for Special Agents: between 23 and 37, with exceptions for older military veterans. And yes, the FBI *does* hire people with industrial instrumentation skill-sets, working on advanced electronic communication and surveillance systems!

6.5 Confidentiality

When you interview with an employer, what is said within that room must be considered confidential information. It is literally nobody else's business but yours and the employer's, and should not be shared with any other employer or any other job-seeker. This is especially true given the fact that employers must be consistent when interviewing a batch of candidates for a job: many, if not all, of the questions asked during an interview will be word-for-word identical for each candidate. Sharing interview questions with anyone compromises the integrity of the interview process because it gives an unfair advantage to future candidates.

As an educator I need to be especially sensitive to this problem. My work brings me into contact with a wide range of employers, and has on occasions even placed me in the same room during interviews. I have also had employers consult me when crafting their own entrance exams, going so far as to use my open-source technical writings as exam question sources. Maintaining confidentiality is a responsibility I do not take lightly, because the consequences of breaching this trust are severe[10].

[10] I was made aware of an instructor at a technical college years ago who blatantly violated this trust in the following manner: after one particularly high-profile employer interviewed his students, he would debrief those students to determine the exact questions they had been asked during the interviews. He would then compile this list of questions and give that list to students for their study. The result was a steadily increasing hiring rate with this one employer, because all of his students knew exactly what they would be asked . . . until one fateful year. Someone at the company decided to completely change all the interview questions, and that year when the employer went to the college to interview this instructor's students, hardly any of them passed the interview. The instructor panicked when he realized his students had been studying for the wrong interview, and in a breathtaking display of foolishness decided to wait outside the interview room to query the next person who exited. As it so happened, the person leaving the interview room wasn't one of his students, and rightfully balked at the instructor's request to divulge interview details. While this exchange was taking place (just outside the door of the interview room, no less!), one of the interviewers stepped out of the room to give this instructor a quick lesson in professional ethics. Shortly thereafter, that employer stopped interviewing students from that technical college.

6.6 Background checks

Although not strictly a part of the interview process, a background checks usually take place after a successful interview. Background checks may include any of the following criteria:

- Criminal records (local, State, and/or Federal)
- Traffic violations
- Sexual offenses
- Terrorist charges or watch-list status
- Drug screening
- Credit report
- Health care sanctions
- Education records
- Employment history
- Professional license and certification verification
- Social Security Number (SSN) verification

Remember that the field of Instrumentation is one where personal integrity matters quite a bit because of the level of trust invested in each and every instrument technician to do a very complex job with high stakes. What every employer looks for here is *good judgment*, which is why checks for criminal activities, traffic violations, and drug screening are commonplace.

Any thorough background check is very likely to reveal if an applicant has misrepresented themselves in terms of legal history, prior employment, education, etc., and so the applicant must be absolutely honest when asked to disclose such history. Nothing stops an application process in its tracks faster than an employer discovering the applicant lied about their background. Furthermore, misrepresentation discovered after an employee has been hired is sufficient basis for immediate termination.

Another form of background check imposed upon many instrument technicians is the requirement to hold special security credentials as a condition of employment, with these credentials usually requiring their own background checks. A common security credential following the terrorist attacks of 11 September 2001 is the *TWIC* (Transportation Worker Identification Credential) administered by the TSA (Transportation Security Administration) and required of all who work on the sea or at a United States facility with its own sea port. TSA conducts its own background check as part of the screening process for each TWIC card holder.

Some Instrumentation jobs have even more stringent security requirements, such as work within the nuclear industry. The Department of Energy (DoE) and the Nuclear Regulatory Commission (NRC) governing nuclear operations within the United States have their own security clearance processes similar to those used by the US Department of Defense (DoD). The DoE “L-clearance” is equivalent to the DoD “Secret” security clearance, while the DoE “Q-clearance” is equivalent to

the DoD "Top Secret" clearance. These security clearances are extremely detailed and strict, may require months to complete, involve interviews of friends and family members in addition to all the standard criteria screened in a regular background check, and typically cost the employer several thousand dollars to execute.

6.7 Drug screening

Abuse of alcohol and other drugs is a deal-breaker for most employers of instrument technicians, and for rather obvious reasons. An instrument technician needs to have a clear mind while on the job, and these substances by their very nature impair thinking. Furthermore, the abuse of these substances represents poor judgment, and as mentioned before employers only want to hire people with good judgment.

Drug tests are commonplace both during the screening process and on the job (at random intervals, or following a mishap on the job). Depending on the type of drug and the test involved, it is possible for the test to reveal drug consumption at a level of sensitivity that cannot distinguish between harmless recreational use and impaired function on the job. What you have to know is, *employers will assume the worst in every case.* If a hair-follicle test for THC (the intoxicating substance in marijuana) is sensitive enough to detect a single use *months* in the past, any employer looking at the results of that test will assume you used marijuana that morning.

This can get especially tricky when laws for certain substances are inconsistent, or inconsistently applied. At the time of this writing (2018), for example, marijuana is approved for recreational consumption by several states within the United States, but it is still a controlled substance in the eyes of the Federal government. When such a disparity exists, employers will often err on the side of the stricter law. This means someone who thought they were legally consuming marijuana might find themselves ineligible for a job in that same state.

Even a legal substance such as alcohol can be problematic for employment. Certainly, showing up at work while drunk will get you fired, but some jobs are so strict in their standards of decorum that even a single alcohol-related conviction (e.g. a "Driving Under the Influence" conviction) is enough to prohibit you from ever working there[11].

Another way people may cause trouble for themselves relating to drugs is by consuming drugs on someone else's prescription. Pain-killers such as Vicodin are popularly prescribed by doctors to help patients manage chronic pain, and these prescriptions place controlled substances within reach of those close to the patient. "Borrowing" someone else's pain medication is very risky because it is not cleared by a doctor *for your use.*

[11] A great example of this is work in the nuclear industry where security clearances are required of instrument technicians. One time an employer came to the college where I teach to recruit students, and their service was inspection of heat exchangers at nuclear power plants, a job for which security clearances were necessary of all their instrument technician. The recruiter announced to the group of 20+ students that even a single DUI on their record would disqualify them from ever applying for that job. I swear, you could have heard a pin drop in that room!

Chapter 7

Growing your career

I have some good news and some bad news for you. Being a pessimist at heart, I'll begin with the bad news: *there is no such thing as job security anymore*. The days of hiring in with a company fresh out of school and remaining there until retirement (earning a nice pension, of course) are long past. In our global economy where whole corporations are bought and sold on a whim, the economic landscape changes so rapidly that one cannot count on any employer to *always* have a job available for them.

What's the good news? Well, the next best thing to job security is *career* security, and this is much more attainable despite the uncertainties of the labor market. Simply put, "career security" means the ability to maintain one's own career despite forced changes in jobs. The field of Instrumentation in particular tends to exhibit a very strong potential for career security because the skill set required to be a competent instrument technician is applicable to a diverse collection of industries. Furthermore, an instrument technician open-minded enough to continue learning new things is easily adapted to related careers such as electrical work, precision mechanical work, process operations, computer programming, data network management, and data analysis.

Maintaining career security does not come automatically for instrument technicians, though. Like any career, it is possible to become too specialized, or simply close off one's mind to learning new things[1], within the field of industrial instrumentation. This chapter outlines some helpful strategies for making the most of this amazing career.

[1] Some jobs within instrumentation make this nearly impossible, as the basic job requirements force you to always learn new things. However, most jobs (regardless of field) will permit some degree of intellectual stagnation, and this erodes career security.

7.1 Building a career path

My general advice to anyone first entering this field, usually as they exit some college-based technical program, is to take the first Instrumentation job that pays the bills and stay at that job for two years before considering a move elsewhere. Some college graduates make the mistake of being too picky as they look for their first job, passing up good opportunities as they wait for the "perfect" job to come along. This is a fatal mistake. Any graduate of *any* professional or vocational program should regard at their degree as having a one-year expiration date stamped on it. Waiting more than a year to secure a job in your chosen career field usually signals a lack of motivation to prospective employers. If you were hiring instrument technicians for your enterprise, who would you prefer to hire: someone who landed a job immediately upon graduation, or someone from the same graduating class who took a year to accept their first position? All other factors being equal, the choice is obvious.

Once you have accepted your first job as an instrument technician (or something closely related in terms of technology and required skills), you should adopt a sense of humility about your own value to the company. A fresh graduate of any Instrumentation program is much more of a liability than an asset, simply due to everything they do not yet know about that industry and that facility (e.g. procedures, unique safety hazards, facility layout, management structure, policies, etc.). Learn everything you can about working safely and effectively, always knowing that your employer accepted a substantial amount of risk in hiring someone as inexperienced as you. This is one of the reasons behind my advice to remain at your first job for two years: *you have a lot to learn about the industry when you first graduate*, and this period will help give you the perspective necessary to make wise choices in the future.

Given the distinct likelihood you won't be working at your first Instrumentation job until retirement, you will need to consider when to secure the next job in your career, and the next one after that. This, of course, depends greatly on the opportunities available to you: both in your current job and also in terms of what other positions are open. If your goal is to maximize career security, you should choose subsequent jobs on the basis of broadening and deepening your capabilities because this alone will raise your value in the technical labor marketplace.

Of course, what most often causes people to switch jobs is the promise of better compensation and/or quality of life. This is hard to argue with, as these are the principal reasons we work at all! If someone finds a new job paying far better, with better benefits, and/or a more desirable work schedule, why shouldn't they pursue it? One caveat to consider is the possibility of professional stagnation. Remember what I said about corporations being bought and sold on a whim? The threat of a great job being yanked away from you due to circumstances such as this which are beyond your control is very real. This threat is commonly realized in less-skilled careers: a person with little to offer in the labor marketplace happens to land a job with great pay and benefits, and proceeds to stagnate for many years. Then one day the rug gets pulled out from under their feet with the news that this great job is ending, and there they find themselves once again with little to offer in the labor marketplace but now with debt and other obligations incurred over years of living with a comfortable income. Although less commonly seen, this can happen to instrument technicians too: you take a job offering great pay and benefits, and you decide to remain at that job long after you cease expanding your professional skill set, then one day you find yourself needing to find another job because your company is folding. Always bear in mind: *there is no such thing as job security anymore.* Plan accordingly.

The drive to maximize your professional knowledge and skill must be balanced against the

hazard of "job-hopping". Remember, the goal here is to maximize your *value* as a technical service provider, and this value includes the quality of reliability. Someone who abandons a job at the first suggestion of new opportunities elsewhere will not be seen as reliable, and this makes them less valuable to anyone seeking stable employees. Again, my general advice to any graduating student of Instrumentation is to take the first instrumentation job that pays the bills, and remain there for at least two years before considering a different job.

Of course, there exceptions to nearly every rule, and the advice to remain at your first instrumentation job for two years is not etched in stone. It would make sense to leave a new job if the working conditions place you in an unreasonable amount of danger, if the employer is unethical, if the job turns out to be something very different from what was promised during the interview, etc. Just make sure if you are leaving your first job for the right reasons, and not just because you sense better opportunity elsewhere. Always remember that *you have a lot to learn* as a new instrument technician, and there are worse things in life than remaining at a sub-optimal job for two years.

A well-executed career should *make sense* when viewed as a series of jobs. Your career path should not appear chaotic or otherwise nonsensical. This is all the more important considering the fact that interviewers are not supposed to ask why you left (or are leaving) your job. The reason(s) for your desire to find new employment should either be obvious to anyone reading your résumé or be logically and ethically defensible should you opt to volunteer this information.

A piece of advice my father once gave me is to always strive to remain at your current job longer than at your previous job. Adopting this mind-set will force you to carefully consider each move, because wanting to stay at the next job longer only makes sense if that job will truly be better for you.

If I were to attempt to lay out the "ideal" career path for an instrument technician, it might look something like this:

1. Begin your career doing contract instrumentation work for a few years, experiencing multiple industries with diverse technical exposure

2. Transition to a permanent maintenance position at a facility with high maintenance load for five to ten years, where you can really hone your troubleshooting skills

3. After having mastered construction and maintenance skills, consider a specialty job where you may deeply explore a particular technology and/or industry sector

4. Grow beyond technical work to become a planner, supervisor, or educator

5. End your career doing consulting work

Of course, this is just one suggested career path. Many others exist, but the real point here is to *always grow* in your professional capabilities. If you optimize your capabilities, the compensation and quality-of-life everyone seeks through gainful employment become much easier to attain. If you ignore professional development and focus solely on compensation, you may find yourself rudely surprised by circumstance.

7.2 Continuing education

Instrumentation is characterized by never-ending technological advancement. In order to remain relevant and marketable in this field you must continually learn. Sometimes the job itself forces you to learn new things, but more often than not the onus of responsibility for continuous learning falls on the individual.

It is important to realize that private, for-profit corporations do not care about your professional development *unless that development profits them.* Therefore, the educational opportunities they extend to you will be limited in general to what serves *their* interest. This is simply the nature of capitalism. Always bear this in mind, so that you will not become complacent by believing your employer's required training and work assignments are sufficient to ensure your own career security.

With these facts in mind, the following subsections outline different methods useful for continuing education in your chosen career.

7.2.1 Find mentors

A mentor is anyone willing to give good advice to someone less experienced. As an instrument technician, you will find potential mentors among fellow technicians, among engineers, among operations personnel, and among others at your workplace. Technician mentors will help you understand how the principles you learned in school apply to the actual work environment. Engineer mentors will help you see beyond the scope of your work as a technician, to learn what is involved in organizing and designing a complete process. Operator mentors will teach you how the existing process works and what information they need in order to most effectively do their jobs.

Foster these relationships. Not only will they augment your career, but you will likely forge lasting friendships as well.

In addition to mentorship, it is always beneficial to develop good working relationships with all personnel at the facility where you are employed. Being able to get along with others and to freely share information is key to being able to get work done fast and efficiently. In particular, you should forge strong relationships with the people you serve: primarily front-line operations personnel. Always remember that as an instrument technician it is your job to make their job as safe and as efficient as possible. They are your "internal customers" at the facility.

7.2.2 Accept any and all training offered to you

Most companies offer some form of technical training to their instrument technicians on a regular basis. This may be initiated by regulatory compliance, by acquisitions of new equipment and technologies, and/or according to a professional development schedule linked to pay raises.

My advice is to take any and all training opportunities extended to you. Regardless of quality, it is all *free* education to you, and you would be a fool to pass it up.

7.2.3 Attend industry conferences

Tradeshows and technical conferences are valuable sources of information and also professional networking. Some of these conferences tend to be manufacturer-centric (e.g. the annual Emerson Exchange) while others are centered around professional societies (e.g. ISA tradeshows).

Like industry training, such events are usually not cheap to attend. However, as with training it is common for employers to pay for their technical employees to attend industry conferences. As with employer-paid training, you would be a fool to pass up any form of free education.

7.2.4 Join professional societies

The ISA is the preeminent society for automation and control, offering much in the way of published literature and formal training. They manage special-interest subgroups focusing on different industry sectors and technologies, which members may subscribe to.

7.2.5 Earn certifications and/or licenses

Professional societies such as the ISA offer recognized certifications as well as training for those certifications. State agencies manage licenses (particularly, electrical licenses) which range from valuable to absolutely necessary[2] in your career as an instrument technician.

7.2.6 Challenge yourself on the job

Volunteer for work assignments that will challenge your skills. Do not opt for the comfortable and familiar when given a choice.

Always strive to learn the *principle* behind the *procedure(s)* used to perform a task. This, in fact, is one of the differences between an excellent instrument technician and a merely competent technician: the excellent technician can explain *why* things are done a certain way, while the merely competent technician only knows *how* things are done.

7.2.7 Read, read, read!

The most detailed and technically accurate resources for self-directed learning in this field tend to be in written form rather than video. This is the primary reason I focus so strongly on technical reading as an educator in this field, because my graduates must be good readers in order to stay current.

Sources to read include:

- **Trade periodicals**, useful for learning about the latest industry trends, regulations, and challenges
- **Equipment instruction manuals**, useful not only for learning procedures, but also principles of operation for equipment
- **Manufacturers' tutorials**, very often well-written guides to how and why their technology functions
- **Scientific whitepapers**, very detailed and technical explanations of new principles and applications

[2] Some states require instrument technicians to also be licensed electricians. Oregon happens to be one of those states.

- **Accident reports** (e.g. US Chemical Safety Board), for learning what *not* to do!
- **New and legacy textbooks**, useful for gaining perspective on technological development

Build up a library of technical literature for your own reference, whether in paper form or digital. Having relevant technical resources at your fingertips is extremely helpful when you need to research something. Do not rely on internet search engines to find what you need when you need it, as these often lead to questionable sources or dead-ends.

7.2.8 Be a scientist

When possible, run experiments on equipment to further your knowledge on how it functions, beyond reading the manual. Many instrument shops will have areas designed to set up and test equipment prior to installation in the field, and you can learn many valuable things (including undocumented features!) about equipment in this way. Furthermore, the testing techniques you hone on the bench will serve you well to diagnose faulty systems in the field!

7.2.9 Share your knowledge

Let's just begin with this statement: *knowledge-hoarding is not a good strategy!* Remember that your true value in this career is based on what you can *do*, not what you *know*. While it is possible to secure a meager form of job security by hoarding information, this is never a successful strategy in the long term. Information has a way of getting free whether you like it or not, and if the security of your job hinges on nobody else knowing what you do, your days in that privileged role are truly numbered.

Another reason for avoiding the hoarding of knowledge is reciprocity: if you don't share with others, those around you will be less willing to share with you. In a complex field such as Instrumentation where no one person knows it all, you *need* others' help, and this help will not be offered if you refuse to help others.

Chapter 8

Managing Finances

Instrumentation can be a very lucrative career. This is both a blessing and a curse: obviously making a lot of money is helpful to modern living, but if you have poor self-discipline a large income can create more problems than it solves. The latter is often the fate of young people entering the field of Instrumentation as their very first career, who have never had to manage adult responsibilities before[1].

Despite devoting an entire chapter to the very important topic of financial management, my coverage of this subject will be brief. I am not a financial advisor, nor would I ever presume to be competent in advising individuals what to do with their money. My advice will be general, but sound.

In short, what every person working a good-paying job *needs* to do is set aside a portion of every paycheck for savings. For some people, whose careers barely cover their basic needs, this might not be possible. However anyone working in the field of Instrumentation should have enough income to ensure consistent contributions to savings.

When I say "savings" I do not simply mean interest-bearing bank accounts. A far more effective strategy for long-term investment is to take advantage of 401k or 403b plans through your employer: these plans allow you do deduct a percentage of every paycheck *prior to taxation* to invest in a range of mutual funds, bonds, or other investment options which will become available once you reach a certain age. The general term for this sort of investment is *tax-deferred*, which means that

[1] This is a sad commentary on the state of parenting and public education in the United States of America. In my humble opinion, American youth are unnecessarily sheltered from the realities of adulthood far too long, making their teenage years a protracted adolescence rather than the preparation for adulthood that it should be. Well-intentioned labor laws prohibiting teenagers from working in any capacity other than menial employment contribute to this same destructive isolation, preventing young people from learning a wide range of practical trades which would serve them well throughout life. I for one am thankful I was raised in a rural environment, where our family farm and workshop was a playground for welding, machining, equipment repair (and modification), and electrical work of all kinds. I'm also thankful for elementary school teachers who taught us about practical finances including compound interest, specifically my 6th grade teacher Mr. Beatty who had every student calculate payments, interest, and principle values for simulated mortgages over the span of the school year. Far too many practical domains are excluded from the American primary and secondary education systems, and far too many American parents fail to take responsibility for the practical education and discipline of their own children. I see this problem every single year as I teach Instrumentation at the college level: young men and women in their 20's lacking self-discipline in matters of time management, finances, and general direction in life.

money is not taxed now as it would be if paid to you in full, but rather will be taxed at some later date[2] when you eventually withdraw from that investment. Many companies offer "matching" plans, which means they will contribute additional funds to your chosen investment, proportional to the percentage you invest from your own paychecks. For example, a "100% match" plan means the employer will match your 401k/403b contributions dollar-for-dollar up to a certain percentage limit, essentially *doubling* the real percentage of your paycheck contribution. Less-generous plans match a specified fraction of your contribution. In either case, these matching funds are essentially *additional income* you get from your employer which you would not receive otherwise if you did not participate in the 401k/403b plan.

Even in the case of companies which do not match pre-tax investments at all, a 401k or 403b plan is incredibly beneficial for your own financial future for the following reasons:

- Your contributions to the investment(s) are *pre-tax*, which means the money you invest is more than it would be if you invested in any other funds or bonds after the paycheck had been deposited in your bank account.
- Since these contributions come out of your income before government taxes are calculated, what they do is effectively reduce the income value seen by the government (i.e. your Taxable Gross Income), which means you pay less income tax every year.
- Most importantly, pre-tax contributions from your paycheck is money you never see in day-to-day living, which means it is money you cannot waste.

That last point bears some elaboration. The fundamental problem of financial management is similar to many other problems in life in that is essentially a matter of enforcing *delayed gratification*. Immediate gratification seems to be the default condition of the human psyche, which in financial terms means people tend to spend whatever they have (and sadly, often more than they have through credit). Rare is the person self-disciplined enough to maintain a strict budget year after year after year without fail. The plain fact of the matter is most people adjust their lifestyles to consume whatever they can afford, which is why most people will tell you they "never make enough money" regardless of their station in life, and why some highly-paid people find themselves paradoxically living paycheck-to-paycheck. Immediately signing up for an investment plan based on pre-determined payroll deduction accomplishes what your own self-discipline is probably not strong enough to do: regularly invest a portion of your income regardless of how you happen to feel or what you happen to crave. This is why it is so important to start your career with this plan: *so you never see the money that's getting diverted from your paycheck into the investment(s), and therefore you will never miss it.*

Even if there were no such thing as a tax-deferred investment plan, automatic payroll deduction toward some form of investment would be beneficial for this same reason. It is difficult to downgrade your lifestyle after becoming accustomed to a higher standard of living. It is easy to create a lifestyle suited to a lesser income if you never experienced what that paycheck would "feel" like without the investment. Again, *you cannot miss what you have never experienced.*

This same strategy of automatic payroll deduction also works very well for charity. Contributing part of your earnings for the benefit of your fellow human beings is an important facet of any healthy culture, as there will always be people in need for no fault of their own. Whether this

[2] And often, at a lower tax rate!

be emergency shelter, food, crisis intervention, educational support, counseling, care services, etc., many people stand to benefit from even the smallest charitable donation. Just like investing, charity is unappetizing when you perceive the loss to your own income. If you set up an automatic payroll deduction toward the charity(ies) of your choosing early in your career, you will not experience the same sense of loss and therefore will have an easier time shouldering that social burden.

Be warned that tax-deferred plans such as 401k and 403b typically do not carry over from one job to another. This means if you have invested money in one of these plans and you happen to leave that employer for another, you may need to *roll over* that invested money into a private plan that will maintain its tax-deferred status. If you fail to do this within a limited amount of time, all that money will be immediately subject to taxation at the current rate, which means you will lose a large percentage of it in taxes. Roll-over options are best discussed with a financial advisor, ideally well in advance of you leaving that job. Another option, sometimes available to you, is to leave the invested money in the previous employer's plan after you leave to work elsewhere.

Some people are so incompetent at managing their own finances that even payroll deductions toward investment cannot help their condition. These are people who *compulsively* spend money. If you are that kind of person, and you're entering a lucrative career, your problems are sure to multiply unless you receive help. For these people, my recommendation is to hire a financial manager to handle your money for you. Whatever you pay this manager for their services will be worth it in the end, because they will do for you what your own self-discipline is not capable of doing. Many options exist for this, but essentially you will be given an "allowance" based on some fraction of your income upon which to live, the rest of your income being wisely invested or spent on essentials by the manager.

The services of a professional financial manager are also useful for people doing contract work, where jobs come and go on an unpredictable schedule. This is a career sector demanding greater-than-normal financial discipline, because you will be making great money while you are working but nothing at all when the job ends. I have known many people possessing enough self-discipline to manage this quite well on their own, but have known others who fell into financial ruin as a result of highly lucrative but highly cyclic contract work.

If you happen to do international work, it is advisable to hire a tax preparation consultant to help manage your income taxes. I have been told by colleagues doing international contract work that the IRS tends to scrutinize such large foreign income streams via regular audits. An IRS audit is no fun, even if all your records are in perfect order, so having a professional's service to assist you in this event is a great relief.

On a general note, I strongly recommend avoiding debt wherever possible. The one area where debt is nearly impossible to avoid is purchasing a home, where the market value of the home and property greatly exceed most peoples' liquid (i.e. cash-able) assets, however most other debts can be avoided with good planning and disciplined effort. This runs contrary to popular American culture, which seems to encourage debt at every turn.

The problem with debt is very simple to explain: *it is a guaranteed loss.* An investment is a gamble, in that you may win or you may lose. A debt, by contrast, is an absolute guarantee you will pay more for something than what it is actually worth when you bought it, due to the *interest* paid with that debt. Another debilitating effect of debt is the psychological burden of knowing you owe money. This kills your economic freedom, and you don't want that.

Debt is especially bad when the asset in question depreciates (i.e. loses market value) over time. This is why car loans are stupid: you pay interest to borrow money to purchase something that is already guaranteed to lose value over time. Always pay for a car in cash. Always. If you can't afford that, carpool or use public transportation until you can afford your own vehicle, then upgrade vehicles *only* when you can afford to do so via outright cash purchases.

Credit cards are an optimized tool for incurring debt, which is why banks aggressively promote them to people. If you have ever run up so many charges on a credit card that you could not pay off the balance, then you lack the self-discipline to use a credit card and you should get rid of it. If you must use a card for certain purchases, use a *debit card* which draws directly out of a banking account and will not let you over-spend.

Interestingly, credit cards are also expensive for the merchant, from whom you make purchases. Any merchant accepting credit cards must pay a fee to the credit card company for that service, and this increases their cost of offering products and services to you. If you wish to support a particular merchant, pay by cash or check, as this saves them the credit card processing fee and gives less of your money to banks.

Instrumentation is a career in which it is entirely possible to *retire* after just a few decades[3] of work, but this is only possible if you manage your finances wisely. Learn how to do so, and implement those lessons *immediately.*

[3] As I write this paragraph (in August of 2018) I cannot help but reflect on the status of a former technical school classmate, who entered the petroleum industry as an instrument technician at the age of 20 and just a few months ago retired at the young age of 50. He took advantage of every investment and savings opportunity offered to him, spent money wisely, and now will enjoy a life of leisure most Americans can only dream of. Based on his social media posts, he now spends a lot of mornings working out at the gym, and most afternoons doing whatever he wants. Isn't this why we go to work? Isn't this the kind of life you would prefer for yourself?

Chapter 9

Cautionary Tales

An intelligent person learns from their own mistakes; a wise person learns from others' mistakes.

In each of these cases, the names and places have been changed (or left unspecified) to protect identity. Each of the circumstances outlined in the following sections are true-life events, some which happened to me and others which happened to colleagues or former students of mine.

9.1 Your First Job

9.1.1 All-day interview

Nancy and Will are soon-to-be graduates of an Instrumentation program at a technical college, and have been summoned to an on-site interview at a large chemical processing plant after successfully passing a pre-screening test. Two other applicants from a different technical college are also summoned to the on-site interview on the same day. After all the individual interviews are complete, the shop supervisor takes all four applicants out to dinner.

The dinner is served at a popular restaurant in town, and as one would expect the server asks the guests if they would like to order any beverages in lieu of water. Both of the applicants from the other college opt to order beers, and proceed to achieve a mild state of inebriation by the end of the evening. Nancy chooses to drink only water, and Will orders a single glass of wine for the evening. The supervisor has several glasses of wine himself.

One week later this chemical company makes their hiring decision: Nancy and Will are both offered jobs, while the two applicants from the other college are declined.

The two failed applicants' excessive drinking during the after-interview dinner was absolutely[1] a factor in this company's decision. The lesson here is very simple: the actual interview begins the moment you make contact and doesn't end until you have parted ways with any and all representatives of that employer. Always bear in mind that one of the major characteristics any employer looks for in any employee is *good judgment*. In fact, judgment often carries more weight than technical prowess for prospective instrument technicians, because technical knowledge and skill

[1] I can say this as a fact, being privy to some details of this particular hiring event.

is much easier to develop over time than bad judgment is to correct. The dinner engagement was an intentional part of the interview process, designed to see how the four applicants conducted themselves in a less formal environment than the interview meeting room.

9.1.2 *Ask* for references!

Karen is a student of Instrumentation, about two months away from graduation. She sets up an informational interview with the Business Development Manager of an instrumentation sales company where she would really like to work. After talking with the Manager for about 45 minutes on the telephone, Karen edits her résumé to emphasize her knowledge and skill areas that are most closely aligned with that company's needs.

After completing the résumé edits, Karen decides to update her References page. Having reached out to the Business Development Manager for the informational interview, she decides he knows her well enough to be one of her references.

Shortly after receiving Karen's résumé, cover letter, and References page, the Manager sends an email message to both Karen and her instructor at the college where she studies Instrumentation. The email is brief and to the point:

> *Please do not cite contacts as references without permission, and please do not bother applying for a job at this company again. Ever.*

9.1.3 The importance of showing up

Jeff was hired at a pulp and paper mill, but was let go after 6 months. The principal reason given for his firing was tardiness: he showed up late to work exactly four times within that period. All four times Jeff apologized for his tardiness, but was dismissed nonetheless.

9.1.4 Do your homework

Samantha applied for a general maintenance position at a food processing plant, which specified some instrumentation-related work within the job description. Six months after hiring on Sally grew tired of doing mostly mechanical maintenance and decided to apply for a different job, one promising a greater focus on instrumentation and control work.

The shop manager was furious with Sally's decision, because she was well-informed at the beginning that this job at the food processing plant would not be 100% instrumentation-related, and she had agreed to those terms nonetheless. Her departure from this employer meant lost investment as well as interrupted business, as she had been hired to help ramp up staffing in a maintenance department that was already too lean.

Had Sally remained on the job for at least a couple of years, the shop manager would have been understanding of her decision. It's one thing to accept a job that isn't perfect in order to gain experience for the next job, but it is quite another to jump ship prematurely simply because what you *hoped* the job might be wasn't what the job actually was (or was advertised to be).

9.2 Safety First!

9.2.1 How to nearly burn an oil refinery to the ground

Just follow these easy step-by-step instructions!

1. Accept a "graveyard" shift assignment following a major *turnaround* event at the refinery, where the entire crude unit was out of service for a month for major repairs and updates. These late-night shifts typically pay more than the standard "day" shift assignment.
2. Get called out by operations to inspect a malfunctioning liquid level transmitter (a Fisher brand *Level-Trol* which uses fluid displacement to sense liquid level in a vessel) that is registering 105% level when the vessel actually empty.
3. Instead of removing the malfunctioning transmitter from service to determine why it had failed, simply turn its calibration screw sufficiently to make it register 0% level to match the empty status of the vessel. There – see how easy it is to be an instrument technician?
4. Contact operations personnel to have them return the level control system to automatic mode, because the transmitter has been "repaired".
5. Immediately walk back to the instrument shop. Do not remain near the transmitter to verify its operation once the vessel begins to fill with liquid.
6. Have the bad luck of the transmitter being on a liquid *butane*[2] distillation column.

Due to this technician's carelessness, the real problem inside the Fisher Level-Trol transmitter was undiscovered and uncorrected: a missing pin caused two pieces to become disconnected from each other. It would not, and in fact *could not* sense liquid level in this state. The technician's action of turning the calibration screw multiple times merely made the transmitter report a different value, while it was still completely unresponsive to the presence of liquid butane inside the vessel.

A few more steps are necessary to cause disaster, though:

1. As an operator, fail to ignore the flat-line trend graph display on your control system showing that distillation column's liquid level mysteriously remaining at 0%.
2. Also fail to ignore multiple high-level warning alarms as the actual butane liquid level increases inside the vessel.
3. Don't call the technician back to check on the "repaired" transmitter.

A short while after the technician's departure, the distillation column filled completely with liquid butane and proceeded to experience high internal pressure as a result[3]. Relief valves at the

[2] Butane is a highly flammable substance, and is commonly used as fuel for portable cigarette lighters. In this particular process it was maintained under pressure to remain in its liquid state at the bottom of the distillation column.

[3] The environment inside of a functioning distillation column is something akin to a tropical rain forest: a pool of liquid occupies the first few feet of the vessel, while the rest of the tall vessel is filled by rising vapors and also by falling droplets of liquid. The counter-current of rising vapors and raining liquid, driven by a heat source at the bottom of the vessel and a heat sink at the top, acts to separate constituent chemicals from the mixture. Substances with a high boiling point tend to collect within the liquid pool at the bottom, while substances with a low boiling point exit the top of the vessel as vapor.

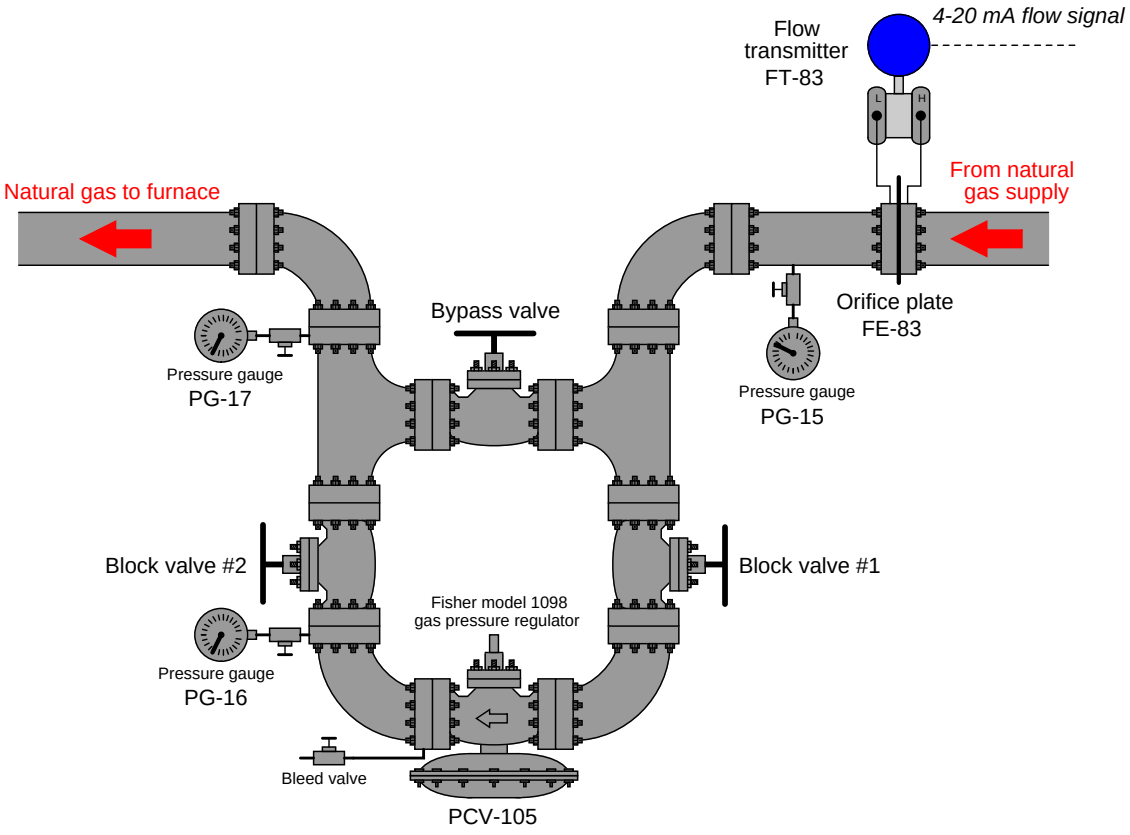
vessel's top lifted to vent this excessive pressure, causing butane to escape in large quantities. As luck would have it, this occurred on a very cold winter night, which meant much of the butane fell to the ground as liquid and slowly boiled into a vapor. A small lake of liquid butane, a couple of inches deep, quickly covered the concrete surface of the unit and spread. Vapors found some source of ignition, setting a good portion of the crude unit on fire. The entire lake of butane was alight, and the still-venting pressure relief valves at the vessel's top were lit like a giant cigarette lighter.

Although no one was injured or killed in this incident, the crude unit required another shut-down and major equipment replacement for an additional month. This nearly caused a whole-refinery shutdown, as virtually every other unit within an oil refinery depends on products output by the crude unit. The refinery was maintained in an operational condition only by reducing each unit's processing flow rate to make the most of reserve feedstocks stored in tanks prior to the original turnaround.

9.2.2 How to nearly blow up a large incinerator

Jennifer works at a large-scale municipal incinerator which uses natural gas fuel to burn garbage. The incinerator happens to be operating in "standby" mode which means a set of *pilot* burners are the only active sources of combustion, while the main burners sit idle and the incineration chamber is empty. These pilot burners are powerful enough to maintain the incinerator at nearly regular operating temperature, awaiting the time when a fresh charge of garbage and more natural gas (through the main burners) may be introduced for incineration.

During this lull in operations, Jennifer is assigned to the preventative maintenance task of rebuilding the pilot burner natural gas pressure regulator. This gas pressure regulator takes in natural gas at a pressure of about 35 PSI and drops it down to a pressure of less than 1 PSI (between 8 and 15 inches water column, with one PSI being equal to 27.7 inches of water column). A set of manual block and bypass valves facilitate service on the regulator without interrupting natural gas flow to the incinerator: operations personnel close both block valves while carefully opening the bypass valve to shunt natural gas past the regulator and on to the incinerator at the correct pressure.



At the time Jennifer arrives at this piping assembly to remove the gas pressure regulator, both block valves have been shut (safety-locked and tagged by operations) and the bypass valve is partially

open, throttling gas flow to the incinerator. Operators have already opened the bleed valve to relieve any built-up gas pressure inside the regulator.

Jennifer un-bolts the regulator's two flanges from the pipe elbows and removes the detached regulator entirely. She moves it back to the instrument shop where she spends about half the day rebuilding it: disassembling, cleaning components, and replacing all "soft" parts with new pieces from a regulator rebuild kit. After reassembly, she pressure-tests[4] the regulator with compressed air to check for leaks, and after that proceeds to move it back out to the field location for re-installation.

After reinstalling the regulator between the two pipe flanges and shutting the bleed valve, Jennifer's next step is to call the field operator to assist with this procedure, as it is policy at this facility to only allow qualified *operations* personnel to manipulate large process hand valves. The operator arrives, and begins by opening block valve #2: the downstream block valve. This introduces low-pressure natural gas to the regulator. Soapy water is applied to the gasket joints to check for leaks there. One this test is passed, the operator opens block valve #1 (the upstream block valve) to apply full natural gas pressure to the regulator. Again, an inspection of the gasket joints reveals no leakage.

As soon as the last block valve is opened, both Jennifer and the operator notice much less noise emanating from the partially-open bypass valve. When in bypass mode, this valve produces a lot of noise due to turbulent gas flow through it. The pressure regulator is constructed with multi-stage "trim" components designed to minimize this noise, and is therefore much quieter. Once both block valves are open and the regulator begins to bear the burden of throttling natural gas to the pilot burners, less gas flows through the bypass valve and it suddenly makes much less noise.

Jennifer is pleased, but the operator looks worried. She hears him mutter, "Why did the gas flow decrease?" Apparently he thinks that less noise from the bypass valve means less gas flow. Reaching for his 2-way radio microphone, he calls the control room to check with the inside operator for the incinerator. "How much flow do we have on the pilot burners?" he asks. The answer is quick: "I show zero gas flow on FT-83."

Now the operator looks very worried. A lack of gas flow means the burners won't operate, which means the incinerator will begin to cool. Re-starting the pilot burners is a lengthy procedure involving air purging, and this is getting too close to the end of the operator's shift for that sort of work. Jennifer, meanwhile, is puzzled. The decrease in noise from the bypass valve is precisely what she expected to hear once the block valves were opened. She quickly glances at pressure gauge PG-16, which reads 12 inches of water column pressure: exactly what it should, because that's the pressure setting of the regulator she just rebuild and tested. Why would the flowmeter register no gas flow?

Jennifer follows the upstream piping with her eyes until she finds FT-83, or at least finds where FT-83 *ought to be*. Instead of a flow transmitter there, she sees a pair of open wires dangling from the end of a conduit. Apparently, someone other than she removed that transmitter from service. This would mean the control room display would register -25% (i.e. a "dead" signal value), and the operator there probably interpreted that reading as zero. The operator thinks there is no gas

[4] This procedure involves plugging off both the inlet and outlet pipe connections and applying pressurized air to the assembly, applying soapy water to all points of potential leakage. If any leaks exist, the soapy water will generate a mass of bubbles, making the leak(s) very easy to locate.

flow, but Jennifer knows better.

Panicking, the operator reaches for the bypass valve's handwheel and begins to open it wide, in an effort to re-establish gas flow and get the pilot burners to re-light based on residual heat. As he does, the remaining noise coming from that valve falls to a whisper. This too makes sense to Jennifer, as a wide-open valve creates less turbulence than a throttling valve and therefore will generate less noise for the same rate of flow. "Oh no, now there's *no* flow at all!" screams the operator. Jennifer looks again at PG-16 which is now registering well over 20 inches of water column pressure and climbing as the operator continues to open the bypass valve.

"Hey, I think there's good flow – look at the gas pressure!" Jennifer says to the operator, pointing to the piping downstream of the regulator. The operator looks over to pressure gauge PG-17 and notices the needle of that gauge pointing to "2". "That's way too low!" he yells, continuing to open the bypass valve. Jennifer points to the gauge she looked at (PG-16), but when both their eyes find that gauge, they notice its needle pointed to *zero*. "We don't have enough gas pressure" yells the operator to Jennifer, "I've got to open up the flow!" He continues to open the bypass valve.

Jennifer looks closely at PG-16. Its needle is actually wrapped fully clockwise with excess pressure until it came to rest on the zero peg. It is literally reading off-scale with too much pressure. She then looks at the face of PG-17 which is now showing "3" and climbing as the operator continues to open the bypass valve. Suddenly she notices the unit of measurement on PG-17: *PSI* instead of *inches of water column*. 3 PSI is greater than 80 inches of water column – far too much pressure for the pilot burners, but the operator is looking at PG-17 thinking its reading is in inches of water column!

At this point Jennifer has three reliable indications that there is plenty of natural gas flowing to the pilot burners: (1) reduced noise at the bypass valve once the block valves were opened, (2) a "pegged" reading on PG-16, and (3) a high gas pressure showing on PG-17. The operator, meanwhile, believes gas flow has stopped for four reasons: (1) reduced noise at the bypass valve, (2) a zero flow indication from FT-83, (3) PG-16 reading "zero", and (4) PG-17 reading "low".

Calling for help on his radio, the operator asks another field operator to visually inspect the incineration chamber for presence of fire. This chamber is located on floor above where the operator stands with Jennifer, and the other field operator is already near that floor. The second operator calls back on the radio: "I've got nothing at all through the viewport – it's totally dark!"

Now the operator has *five* reasons to think the gas flow has stopped. Jennifer wonders why the glass viewport doesn't clearly reveal the functioning pilot burners, until she steps aside to look at the exhaust stack for the incinerator: thick black smoke is billowing out the top of it, a clear indication of "rich" combustion where too much fuel mixes with too little air. She quickly realizes what is actually happening: so much natural gas is entering the incinerator through the wide-open bypass valve that the pilot burners are "flooding" with excess fuel. The dark soot produced by this rich condition is completely obscuring the second operator's view of the burner flames.

Jennifer also realizes this is a very dangerous condition: with all that natural gas pouring into the incinerator, a violent explosion is possible. She must act quickly to avert a disaster. At first she tries reasoning with the operator, pointing out the missing flow transmitter (FT-83), the "pegged" pressure gauge PG-16, the wrong unit of measurement on PG-17, and the black smoke issuing out of the incinerator's exhaust stack. That black smoke may have been enough to change the operator's mind, but he doesn't bother to look up at it to see for himself – he's too convinced the gas flow has

stopped.

Having exhausted the option of reasoning with the operator, she considers her limited options:

- Physically overpower the operator and close off the bypass valve to establish normal gas flow
- Flee the scene of the impending disaster
- Find some other way to convince the operator to reverse his steps

The first option (assault) would spell the end of Jennifer's career. The second option would save her life, but no one else's. Was there a third option?

Suddenly an idea occurred to Jennifer. Pointing to her wristwatch, she asks the operator, "Hey, it's nearly the end of the shift. Why don't we just put everything back where we started and tackle this tomorrow?" After a pause that seemed to last an eternity, the operator agreed and began to close the bypass valve. Jennifer watched in relief as the black smoke dissipated and PG-16 returned to 12 inches of water column. When the operator closed off block valve #1 and the bypass valve's raucous noise returned, the operator breathed a loud sigh of relief, "Thank goodness, the gas flow is back!" The second operator confirmed over the radio that he could see fire through the viewport again.

"All good now . . ." said Jennifer, returning to the instrument shop shaking with adrenaline.

What lessons shall we draw from this incident? First and foremost, some people are truly unqualified to be operators. Why any operator should think that *opening* valves on a pipe would somehow *reduce* the flow rate of gas through that pipe is anyone's guess. We may also fault the control room operator for failing to notice the difference between a -25% flow reading and a *zero* flow reading. However, there is plenty of blame shared by maintenance personnel. Flow transmitter FT-83 should never have been removed from service without the operations personnel being notified of that fact. PG-17 was the wrong type of pressure gauge (calibrated in PSI rather than inches of water column). Jennifer should have noted these details prior to doing the regulator rebuild job, and should have replaced PG-17 before re-commissioning the regulator.

Perhaps the most important lesson of all regards the art of persuasion: when logic fails to convince, you may find an appeal to laziness more effective. The operator was too convinced in his original hypothesis (no gas flow) to listen to reason, but when presented with an option that avoided overtime work he complied. Human beings are naturally more receptive to suggestions that will make their lives easier, and naturally resistant to suggestions implying hardship or effort.

The job of an instrument technician is much more than just technical. You will be working with many different people, and will need to convincingly present information to them in order that they may make informed decisions about complex systems. Never take this role for granted!

9.2.3 How to nearly be cut in half by a high-pressure jet

Frank is a new instrument technician at a chemical processing plant. Today is his twentieth day on the job. Although he has some experience already as an instrument technician at an electrical power plant, he is finding this chemical plant to be full of challenges. The piping systems are a labyrinth, and each area of the facility contains about ten times the amount of instrumentation as the power plant he used to work at. This chemical plant is also much older than the power plant, and had been upgraded many times over. This fact also made it an interesting place to work: lots of history and modifications that weren't necessarily well-documented.

Due to the complexity of this facility and his relative inexperience on this job, Frank is often accompanied by a field operator when doing even simple tasks. Today he is asked by the shift operations manager to check the calibration of pressure transmitter PT-153, for a high-pressure chemical reactor vessel. This is a commonplace task, consisting of manipulating a set of small "manifold" valves connecting the pressure transmitter to the reactor vessel. With the "block" valve shut and the "equalizing" valve open, the pressure transmitter will experience zero pressure and should report that to the control system and to the operators in the main control room. If the display registers anything other than zero (exactly), it means that pressure transmitter is out of calibration.

Frank walks out to the reactor vessel led by Bruce, a field operator. Bruce is a veteran of this facility, having worked this unit for over ten years. He is also a bit annoyed with having to be Frank's escort for the day. Bruce visually locates pressure transmitter PT-153 and begins to instruct Frank on the manipulation of the manifold valves.

"Shouldn't we notify the control room first, and have them put the controller in manual mode?" asks Frank. "Just do what I tell you" barks Bruce, pointing again to the pressure transmitter. Frank decides against arguing with Bruce, and hangs his leather tool bag on a pipe rack near the reactor vessel. He then reaches for the manifold block valve and begins to close it. After that, Frank turns the equalizing valve handle to the "open" position. As soon as he reaches for his 2-way radio microphone to call the control room operator to verify the pressure reading of PT-153, Frank hears a loud report. Suddenly the air is filled with a powerful odor, and Frank is dismayed to see a jet of high-pressure gas venting out of a pipe near his toolbag. This jet sliced through the leather strap of his toolbag, causing all his tools to spill to the ground! Both Frank and Bruce run up-wind for safety, Bruce activating the emergency shutdown system on his way out of the unit.

Here is what happened: the purpose of pressure transmitter PT-153 was to report the chemical reactor vessel's interior fluid pressure to the control system, which would then regulate that pressure by throttling a control valve (PV-153) letting product out of this vessel and onward to other portions of the unit. When Frank blocked and equalized the pressure transmitter, causing it to report zero pressure, the still-active control system automatically slammed control valve PV-153 shut in an effort to re-establish pressure inside the vessel. In reality the vessel never lost pressure at all, but the control system *thought* a pressure drop had occurred due to the pressure transmitter's now-zero signal. The vessel's actual pressure skyrocketed, causing a "rupture disk" to burst. Rupture disks are overpressure safety devices, designed to break and vent fluid to atmosphere in the event of excessive pressure. The vent pipe was unfortunately located near enough to ground level that it could pose a threat to nearby personnel. Had Frank called the control room operator to have

them place pressure controller 153 in manual mode prior to manipulating the transmitter's manifold valves, the control system would have held control valve PV-153 at a constant position during the pressure signal outage, and there would not have been a dangerous overpressure event.

After evacuating the unit, Frank looks around for Bruce. He sees Bruce busily working to shut block valves as part of the unit shutdown procedure. Soon the area is swarming with more operators, each doing their part to bring the unit to a safe "shutdown" condition.

Frank leaves the unit and gathers his frayed nerves. That high-pressure jet was only a few feet away from where he had been standing, and it was powerful enough to slice a leather strap as easily as a silk ribbon. By the time he returns to the instrument shop, Frank discovers the shift operations manager has already called his boss to blame Frank for this mishap! Apparently Bruce the field operator took no responsibility for his order to equalize the transmitter despite Frank's suggestion to first call the control room.

Frank proceeds to explain what happened to his boss, who thankfully is understanding and also respectful of Frank's competence and integrity.

What lessons can we learn from this? First and foremost is to never allow yourself to be bullied by any other employee pushing you to take action against your judgment. As a general rule, you should always take time to question and to carefully think through the potential consequences of every step you take on the job. This is especially true when the process is in a regular operating state and no emergency is at hand. There is literally no good reason to rush through a job, especially if you aren't fully confident in the safety of your actions.

Another important lesson to learn here is that some people will blame you for their mistakes. This is especially true when you are new on the job and the other person is no longer probationary. In this case, Bruce was the ten-year veteran who definitely should have known better than to equalize a transmitter without first securing the control system in manual mode, while Frank was the "newbie[5]" who made an easier target for blame due to his inexperience on the job.

In case you were wondering, this all ended well. No one was harmed or injured in any way from the overpressure event, Bruce's scapegoating of Frank fortunately didn't stick, and Frank learned a very valuable lesson about the culture at his new workplace.

[5]This is but one of many unflattering terms applied to anyone new on a job.

9.2.4 When to disobey your boss

Jack is a newly-hired instrument/electrical technician assigned to do a routine visual inspection of buswork[6] on a medium-voltage (4160 Volt) motor control center (MCC) in a large water treatment facility. To do this job, Jack must first request operations personnel to shut off all electrical loads powered through this system, then he must shut the breaker off, rack it out[7], and apply a safety lock and tag (lock-out/tag-out). After that, Jack will need to verify the absence of electrical potential by examining voltmeters on the MCC panel and by attempting to re-start electrical loads fed by that panel. Only then it is considered safe to remove the access covers to expose the copper buswork for visual inspection.

After removing the sheet metal covers over the busbars, there is one more safety check to perform prior to commencing the inspection: testing voltage from each busbar to ground using a high-voltage voltmeter. Despite the prior safety precautions one can never be too careful when dealing with such lethal voltages!

Ray, who is the foreman for that section of the maintenance shop, directs Jack to use a "tic-tracer[8]" for that final voltage check rather than the approved voltmeter. Jack protests, knowing that a tic-tracer needs to be placed in close enough proximity to the conductor to pose a hazard[9] at the 4160 Volt level. Ray continues to insist that Jack use the tic-tracer despite Jack's protests, and invites himself along to the work site with Jack carrying the tic-tracer. Jack retrieves the approved high-voltage voltmeter from the shop's tool room and proceeds to the MCC building.

Once Jack and Ray arrive at the MCC, Jack performs all the steps previously described, including using the approved voltmeter to do a final safety check on the busbars. After this, Ray extends the probe of the tic-tracer toward one of the de-energized busbars. Paradoxically, it *tics* once. Jack re-tests with the high-voltage voltmeter to ensure the busbar is indeed energized, and it still registers 0 Volts. Ray tries the tic-tracer again and finds it gives a "false positive" tic once every few times he approaches the busbar.

"Good thing we brought a *real* voltmeter" says Jack.

A good lesson to take away from this incident is to stand your ground when someone suggests

[6] In high-power electrical systems, solid copper metal bars called *busses* are used to conduct electricity rather than wires. These metal bars are held away from any other electrically conductive components by *insulators*. Both the busbars and the insulators should be inspected at regular intervals for dust and debris and for any signs of distress (discoloration from heat, evidence of arcing, etc.).

[7] The act of *racking out* a medium-voltage circuit breaker involves unplugging it from its cubicle in the MCC assembly so that the load bus will remain de-energized even if the breaker contacts happen to close. If tripping the circuit breaker is analogous to flipping the toggle switch of an appliance to the "off" position, racking out the circuit breaker is analogous to unplugging the power cord from the wall receptacle.

[8] A *tic-tracer* is an inexpensive voltage-sensing device which senses the presence of ground-referenced AC voltage via electrical capacitance, generating audible "tic" pulses to signal voltage. The device has a plastic-covered probe which only needs to be *close* to the conductor to sense voltage – direct contact with the conductor is not required.

[9] At elevated voltage levels, avoiding direct contact with the power conductor is insufficient to maintain safety. One must remain a certain minimum distance from an energized conductor to avoid *flashover*: a phenomenon where the air within the gap separating you from the conductor ionizes from the high potential and becomes electrically conductive, causing an arc to jump between you and the conductor. According to the 2015 version of the NFPA 70e Standard for Electrical Safety in the Workplace, the limited approach boundary for such a medium-voltage busbar is just over 2 feet. The approved voltmeter Jack wants to use has a three foot long probe. The tic-tracer's probe is 6 inches long.

a less-safe method of doing a job, no matter who that person might be. You may find yourself in a similar situation, especially when working alongside someone who learned their trade before the days of NFPA 70e and comparable industrial safety standards. Remember that the law is on your side as far as workplace safety is concerned!

It pays to educate yourself on all applicable safety standards. One thing Jack could have done here was to cite the NFPA 70e standard on safe approach distances for 4160 Volt circuits, but he didn't. All he knew was that the tic tracer wasn't physically long enough to ensure a safe air gap between himself and the busbar, but the approved voltmeter was. Citing a national safety standard is a sure way to settle a safety argument.

9.2.5 How to get yourself black-listed

Wendy is working as an instrument technician for a contractor, doing work mostly in Alaska in the north slope oil fields. Like all contracting jobs, the work comes and goes, but Wendy has learned to budget wisely which allows her to enjoy months at a time without work because when she is working the income is phenomenal.

During one of her breaks from work, Wendy is doing maintenance on her home. Cleaning the gutters on her home one day, she slips and falls from the ladder. The landing was hard, and although no bones were broken she did receive a large bruise from the fall and as a result is left limping for days afterward.

Wendy's brother Ralph has been disabled for years with a severe spine injury. His doctor regularly prescribes Vicodin for pain relief which means Ralph always has an ample supply, and one day while visiting Wendy he offers some of that medication to her. She gladly accepts it, knowing it will help ease her pain and general stress.

One week later Wendy receives a telephone call from her contract employer announcing a new job in Alaska. This job will require a drug screening as usual. Wendy fails the drug screening because it detected the Vicodin she took – medication for which she has no doctor's prescription.

She tries to explain to her employer that it was her brother's Vicodin, and that she only took it because of the pain she was in after falling from her ladder at home. The employer not only is unsympathetic, but black-lists Wendy and never calls her again.

All it took was one lapse of judgment on Wendy's part to derail her lucrative career.

Appendix A

Epilogue

Over the decades I have been teaching Instrumentation I have seen hundreds of people complete their education for this field and enter the workforce successfully. Those that have been most successful seem to be those who are the most *interested* in it for its own sake. A number of people choose this career path because it is lucrative, but at the end of the day money just isn't enough to keep you inspired to do good work and grow professionally. You probably know of people in your own life who are competent at their good-paying jobs, but *hate going to work*.

Don't let this be your fate. You *do* have a choice of employment in a free market, and if there is any wisdom I can pass along to you in this regard, it would be to choose a career that engages you on multiple levels. If that career is working as an instrument technician, then hopefully this guide will give you some useful information. If that career is something else entirely, then maybe this Epilogue will be the most useful part. Whatever the case, *don't waste away your working life at a job you hate*.

This doesn't mean that the "right" career choice will always make you happy. Life is never that simple. *Everyone* dislikes their job from time to time. However, on the whole your work life should feel rewarding on more than just one level. If not, you've probably made a poor choice.

And remember kids – be safe, and try to have some fun!

Appendix B

Version history

This is a list showing all significant additions, corrections, and other edits made to this tutorial. Each entry is referenced by calendar date in reverse chronological order (newest version first), which appears on the front cover of the tutorial for easy reference. Any contributors to this open-source document are listed here as well.

14 August 2018 – renamed the *What Makes a Valuable Employee?* chapter, and significantly expanded its contents to include discussions of human capital, as well as "red flag" behaviors seen in students. Also added general advice to the *Managing Finances* chapter.

5 January 2018 – clarified when to use "Enclosure" versus "Attachment" at the end of a cover letter. Changed the title of the "Interviews" chapter and expanded coverage to reflect more about the screening process. Added an example of an interviewee using the STAR method to answer a typical behavioral question. Added information about security clearances as required for work within the nuclear industry. Some grammatical edits made throughout the document as well.

29 December 2017 – added the *Growing Your Career* chapter.

6 November 2017 – amended statement concerning lack of merit consideration in union hall work assignments. Thanks to Paul Meyers for clarifying! Also added detail on systems engineering work, particularly the phases of a typical engineering project.

27 December 2017 – added the *Cautionary Tales* chapter.

25 September 2017 – elaborated on references, and also the Epilogue.

21 September 2017 – added comments on typeface and font choices in résumé and cover letter documents.

18 September 2017 – document first published.

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