Who is running your plant at 3.00 am?

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It is important to have qualified and trained process technicians working in oil refineries and chemicals plants. Process technology education programs in the United States, United Kingdom, Germany, India, Singapore, South Africa and Australia are discussed. Two-year community college process technician training programs have been successful models especially when combined with a six-month period of industry experience.

The title of this paper refers to the very important issue of who has the responsibility for the safe operation of chemical plants and oil refineries 24 hours a day, 7 days a week and 365 days a year, including holidays. Management and technical staff typically work five days a week from 8.00 am to 5.00 pm (and usually longer hours than 8.00 am to 5.00 pm). At 3.00 am the operational responsibility will be in the hands of a shift supervisor. Working for the shift supervisors are the process technicians. (for the sake of clarity, we will use the term process technician, meaning operating technician, operator, console technician etc.) The shift supervisors and process technicians are there at 3.00 am every day, determined to run the facility as safety and efficiently as possible.

Who are these people to whom this round the clock responsibility is delegated? How are they hired, what is their skill level, how are they trained? This paper addresses the skills level and training required of those who aspire to become process technicians. The challenging question is "what should the education and qualifications be for a person being wanting to be employed as a process technician in a chemical plant or an oil refinery?" In the opinion of the authors senior management of oil and chemical companies should emphasize that the safe operation of their facilities depends on the training and expertise of personnel who are not degreed engineers or chemists but who are dedicated technicians with a two-year associates degree or diploma.

There are several ways to be recruited as a process technician:

- By being hired in with no process technology experience and then being trained on the job,
- Having several years' experience with another company or facility as a process technician before moving to a new company,
- Having little or no process or industry experience but having graduated from a two-year process technology (PTEC) program at an accredited college or university.

The authors have examined the competence training and hiring process in several countries and present their findings and conclusions.

Process Technician Training and Competence for chemical sites in the UK

The UK health and safety legislation is goal setting and not prescriptive. The legal requirements set the outcome to be achieved and not the process or method to be adopted to realise that outcome.

In broad terms for chemical facilities within in the UK there is a requirement under Seveso III (Control of Major Accident Hazards Regulations, 2015)[1] to take all measures necessary to prevent a major accident and to mitigate the consequences should one occur. An important 'necessary measure' is to have sufficient competent persons on site at all times to manage risks, control the processes and deal with abnormal conditions and to give effect to the emergency arrangements.

For upper-tier COMAH sites, within the Safety Report, the company needs to provide a description of the approach to the arrangements for selecting and recruiting competent personnel, identifying and meeting their training needs, monitoring their performance and allocating roles and responsibilities as appropriate. For all facilities the arrangements for selection, training and deployment of resources will be closely examined during routine regulatory inspections. The Safety Report should also explain how senior management provide sufficient human resources to maintain adequate staffing levels for the full range of safety-critical tasks at the establishment.

Ensuring adequate standards and levels of competent staff does not just relate to the operation of the plant and processes but will extend to the design, commissioning, inspection and maintenance of such facilities, including the ability to undertake risk assessments, implement improvements and manage change. This requirement for adequate competence is not restricted to technical staff and extends all the way up to the senior managers and directors, who also need to be suitably competent to provide oversight and leadership in process safety.

In practice, this flexibility of goal setting legislation is underpinned by the industry and regulator cooperating to provide guidance and generate training standards and process safety training. Such standards include COGENT Skills for Science Based Industries Process Safety Leadership (PSL)[2], Process Safety Management Foundations (PSMF)[3], Process Safety

Management for Operations (PSMO) , The three process safety courses which have been developed around national training standards content, are approved by the UK Process Safety Management Project Board. These management training courses are supplemented by specific technical training such as the Life Sciences and Industrial Science Manufacturing Technician Apprenticeship. In addition, organisations such as the Institution of Chemical Engineers provide bespoke and targeted training.

University Bachelor Degree courses in chemical engineering are available for many UK universities together with post graduate MSc qualifications from universities such as Aberdeen and Sheffield and MSc in Chemical Process Engineering from University College London, UCL.

Just about to launch in the UK is a new three-year vocational Risk Management Professional Masters' Degree under the Government's Apprenticeship Scheme[4]. This is aimed at the engineering and manufacturing sector but will form a good foundation for process and major hazard industries. This apprenticeship provides evidence of knowledge, skills and behaviours in line with the professional registration requirements for Chartered Engineer and may also align with the professional registration requirements of relevant professional bodies regulated by the Engineering, subject to further specific experience.

Within the UK there is guidance on how to ensure adequate staffing levels at chemical and major hazard facilities. HSE has published guidance on 'Assessing the safety of staffing arrangements for process operations in the chemical and allied industries' (Entec CRR348/2001)[5]. This has been supplemented by the Energy Institute's guidance on 'Safe staffing arrangements'[6]. This guidance is not designed to calculate a minimum or optimum number of staff to control a process, but to flag where staffing arrangements may not be sufficiently robust.

Process Technician Training and Competence for chemical sites in the Germany

As with the UK, German authorities do not specify minimum staffing levels or minimum qualification levels for chemical plants as the operating responsibility (including staffing) lies with the company. The Competent authority in Germany expects the company to have sufficient (number) appropriately qualified staff to be able to operate safely at all times. This means that the night shift is staffed similarly to the day shift for the relevant operations.

Training is part of a continual programme. In a control room you would expect to find a number of qualified trade employees under the supervision of a master-trade qualified member of staff. For the whole of the plant there is likely to be an operations engineer (bachelor degree, more likely master's degree qualified) supervising the whole of operations, but not generally in the control room all the time. On a continuous process there will be a duty engineer who is on call. The staffing ratios will depend on type of operations, degree of automation, complexity of plant etc. In addition to these operations staff there will be maintenance and inspection staff of varying grades of qualification depending on the site.

There are formal technical training frameworks within Germany. Firstly, there is an apprenticeship based 'Chemikant- trade'[7] regulated under 'Ordinance on Vocational Training as a Chemist, 10 June 2009'. This training takes three years and six months and comprises both compulsory and elective elements. The next grade Industriemeister – Fachrichtung Chemie:[8] This is a "master trade qualification". The requirements are a completed, recognised "trade" qualification in a chemical trade or a recognised trade qualification plus at least one-year practical experience, or at least 4 years practical experience. Next is a State-Certified Engineer / State Examined Technician. The training takes longer than the "master trade qualification". Within the European and German Qualification Framework (EQR/DQR) the qualification is set at level 6 of 8. This would put it at the same level as the master trade qualification or a bachelor qualification. However, the VDI (Association of German Engineers) is clear that the competency of the three qualification is very different, and it should not be assumed that the three qualifications enable that the same work can be carried out.

Graduate training is Bachelor (BSc, BEng) – the bachelor qualification is issued by a Hochschule or Universität (tertiary education). Chemical Engineering qualifications may have a number of titles: Chemieingenieurwesen, Verfahrenstechnik, Technische Chemie, DECHEMA, the German Association of Chemical Engineering (sister organisation of the IChemE) published recommendation on education in the field of process and plant engineering within the Bologna Process (2012). A Master's degree is also available building on the formal bachelor graduate qualifications[9].

Therefore, the competency and staffing requirements within the UK and Germany are broadly similar with the main difference being in the structured training available for technicians and trades within Germany

The United States

Process safety in the oil and chemical industry in the United States is regulated by the Occupational Safety and Health Administration (OSHA) process safety management regulations and by the EPA's risk management program regulations. In those regulations there are no specific process technician recruitment and hiring standards but there are requirements for on the job training i.e. after the employee has been hired. For pre-hiring a Process Technician, there may be two-year technical colleges locally available which offer associate degrees in chemical process technology (PTEC). The availability of a two-year associate degree will depend on the location of the manufacturing facility. Colleges offering a two-year PTEC associate degree are typically located near concentrations of oil refineries and chemical plants e.g. the Gulf Coast area of Texas and Louisiana.

A recent paper in the *Journal of Technology, Management and Applied Engineering* by Johnson and Bartsch[10] states that one year of PTEC education is worth 5.3 years of experience as a process technician. Refineries and chemical plants can save significant training dollars by hiring PTEC graduates with two-year degrees.

In the United States, major oil refining and chemical manufacturing complexes are concentrated in three states –Texas, Louisiana and California. Consequently, outside of these three states the industry tends to be located at individual facilities. This makes it problematic to have local educational institutions where potential employees may be trained in the basics of PTEC.

The North American Process Technology Alliance

NAPTA (http://www.naptaonline.org/) is an organization of 45 Process Technology (PTEC) education providers and their business, industry, and community advisors cooperatively working toward their common goals. The colleges are located around the United States but with a cluster along the Gulf of Mexico Coast. For example, there are NAPTA colleges in Alaska, North Dakota, Pennsylvania, California, New Jersey, Washington, Illinois and Oklahoma as well as in the Louisiana and Texas Gulf Coast region. In Pennsylvania, the Community College of Beaver County offers PTEC courses using the NAPTA core curriculum to serve the needs of the new Shell ethylene cracker under construction near Pittsburgh.

NAPTA is the national standard–bearer of the PTEC curriculum. NAPTA audits college PTEC degree programs in North America and endorses those programs that meet its criteria. Approximately 20 colleges have received the NAPTA endorsement. The core courses offered at NAPTA endorsed colleges and universities are:

- Introduction to Process Technology,
- Process Technology I – Equipment,
- Process Instrumentation,
- Process Technology II – Systems,
- Safety, Health and Environment,
- Process Technology III – Operations,
- Quality,
- Process Troubleshooting.

As Eric Newby, the President/Executive Director of NAPTA says *"We don't teach them how to run plants, we teach them how plants run",* referring to the core technical curriculum in the PTEC programs. With an extensive background in process operations, Mr. Newby is an ardent advocate for PTEC education. He organizes NAPTA instructor conferences, troubleshooting competitions for PTEC students and other national meetings to coordinate NAPTA activities.

The Houston, Texas Area

The highest concentration of petrochemical plants and oil refineries in the United States is in the Houston Gulf Coast area. In that area there is a continuing need for qualified process technology technicians. A consortium of nine colleges with 32 campuses has been formed in the greater Houston area. These colleges offer two-year associate degree with the opportunity to continue to study for a bachelor's degree. They offer many courses leading to job opportunities in the process industries. Courses are available in process technology, instrumentation, electrical, welding, pipefitting, machining and millwright.

The colleges are connected by a website www.petrochemworks.com which permits potential students to:

- research the diverse types of employment opportunities in the process industries,
- determine which companies are hiring process technicians. A quick search of the *petrochemworks* web site showed 14 major companies in the Gulf Coast area that were hiring with over 11,000 job openings listed,
- research where to get PTEC training and become job marketable in two years. The web site lists all 32 campuses and the courses that they offer. It states that "You can make $70,000 or more", certainly an incentive for an 18-year-old just leaving high school!

Mr. Layton Childress, Dean of Applied Sciences at Lee College in Baytown, Texas (one of the colleges on the *petrochemworks* website) reported that the two-year associate degree program gets lots of support from business and industry. For example, the very comprehensive *petrochemworks* web site is funded by the banking company JP MorganChase and &Co. In addition to the academic portion of the program, the oil and chemical companies hire students as interns for 8 to 12 weeks. The internship allows the facilities to evaluate potential employees before offering them a fulltime position. Not every student survives the

academic rigor. In a typical intake of 24 students, the college may lose 5 to 10 students before completion of the two-year program.

United States – Oklahoma

Not every two-year college is located near a cluster of chemical plants or oil refineries. One example is Northeastern Oklahoma A&M College or NEO A&M located in Miami, Oklahoma. NEO A&M is a member of NAPTA. Dr. Mark Grigsby heads up the PTEC program which has been offered at the college since 2012 when the college was approached by Ceradyne Boron Products LLC, located in Quapaw, Oklahoma about 10 miles from Miami. Ceradyne was having issues attracting qualified employees to work in its boron facility which manufactures products used in nuclear power plants. Ceradyne is now a wholly owned subsidiary of the 3M Company.

NEO A&M has used its PTEC program to help promote economic development in Oklahoma. In addition to 3M Ceradyne, companies using the program include CVR Refining, CF Industries, Umicore, Inc. and an Evonik Industries chemical plant. Dr. Grigsby says that the goal of the program is to provide candidates for good paying jobs and to meet the needs of the business community. One issue that he reports is that it can be difficult to recruit PTEC students from high schools because in the rural areas of Oklahoma and Kansas potential recruits for the program don't understand what process technology is.

The NEO A&M PTEC program has about 30 students currently enrolled. A few of those students are challenged by the mathematics and chemistry sections of the program and they may decide to drop out. On the other hand, everyone who graduates after two years is offered a position in industry.

United States – Montana

Another example of a PTEC program located away from the United States Gulf Coast concentration of chemical plants and oil refineries is in the northwest U.S. state of Montana, bordering on Canada. Its largest city is Billings with a population of 110,000. There are three refineries in the Billings area – ExxonMobil, Phillips 66, and CHS. Another refinery, Calumet Montana Refining, is in Great Falls, Montana, about 200 miles from Billings.

Montana State University Billings (MSUB) offers a two-year Process Plant Technology Associate of Applied Science degree. Andrew Sullivan is the Instructor, Process Plant Technology. He is a former ExxonMobil refinery supervisor. All the courses that must be taken are listed on the MSUB web site:
http://www.msubillings.edu/citycollege/programs/pos/busindustry/ProcessPlantAAS.htm

The program graduates approximately 20 graduates per year. Typical incoming students range from recent high school graduates to middle aged individuals. Many students have served in the military. Upon completion of the two-year program, they can apply for a position at one of the oil refineries or chemical plants in Montana or the adjacent states. Some hiring companies have a policy of hiring either PTEC graduates from MSUB or applicants with at least five years of relevant experience. According to the MSUB web page newly hired PTEC employees can expect to earn an average of $US56,821 per year.

Singapore

Probably the most interesting and comprehensive program that the authors examined was in Singapore. It is an island city-state just south of the Malaysian peninsula with an area of 277 square miles or 719 square kilometres. Its population is 5,607,000, making it the 3rd most densely populated country in the world (after Macau and Monaco). Jurong Island, connected to the main island of Singapore by a causeway, is home to Singapore's oil refining and petrochemical industries. There are reported to be more than sixty oil and chemical industry facilities on Jurong Island. Singapore is one of the top three oil refining centers in the world.

Because of the magnitude of the chemicals and oil sectors on Jurong Island there is a continuing demand for well-trained process technician candidates to work at the many facilities on the island. The Singapore Institute of Technical Education (ITE) fills that need. ITE is a public vocational education institution that provides pre-employment training to secondary school leavers and continuing education and training to working adults. It is part of the Ministry of Education.

For ITE's chemical process technician training program, between 200 and 300 students are accepted each year. They are 70% male and 30% female. Students begin the program at age 17, when they have completed secondary school. The goal of the training is to be qualified for a position as a junior process technician in the oil refining or chemical industry.

The course at ITE lasts for two years – it includes instruction on safety, security, occupational safety, plant operations, process instrumentation and control, process equipment, quality assurance and risk assessment.

For 5 ½ months of the 2-year program the students work as interns in a facility, earning 450 Singapore dollars per month. This permits them to learn about process equipment such as reactors and furnaces not available for them to work on at ITE. At the end of their two years of education at ITE and in industry they receive the National Institute of Technical Education Certificate (*Nitec*). Upon leaving ITE all males perform two years of national service in Singapore. This may be in the Singapore Armed

Forces, the Singapore Police Force or the Singapore Civil Defense Force (fire department, ambulance service and emergency response). After their national service they may apply for a position in the chemical process industry. Approximately 80% of the ITE graduates are hired. Typically, the females work in laboratories and the males as process technicians.
The ITE graduates may continue their education to get a polytechnic diploma or a university degree.

India

With a population of more than 1.3 billion, an expanding automobile market, active chemical and pharmaceutical manufacturing sectors, there is an increasing need for well qualified chemical process technicians. There are 24 oil refineries in India, including the world's largest, the Reliance Industries Limited refinery in Gujarat with a published capacity of 1,240,000 barrels per day. In recruiting advertisements in India for chemical process technician (typically called Attendant Operator Chemical Plant or AOCP) common hiring requirements are a BSc in chemistry or chemical engineering, a two-year diploma in chemistry or chemical engineering, preferably with chemical industry experience.

In India a two-year diploma in chemistry or chemical engineering may be earned at an Industrial Training Institute (ITI). They are approved by the Directorate General of Training (DGT), a body within the Indian Ministry of Skill Development and Entrepreneurship. The Ministry was set up in November 2014 to coordinate all skill development efforts across the country. Industrial Training Institutes predated the Ministry of Skill Development and play a vital role in the economy of India especially in terms of providing skilled manpower in different sectors with varying degrees of expertise.

The Directorate General of Training consists of the Directorate of Training and Directorate of Apprentice Training. This includes a network of Industrial Training Institutes in each of the states; Advanced Training institutes (ATIs), Regional Vocational Training Institutes (RVTIs) and other central institutes. A number of training programmes catering to students, trainers and industry requirements are being run through this network. The building blocks for vocational training in the country - Industrial Training Institutes - play a vital role in the Indian economy by providing skilled manpower in different sectors with varying levels of expertise. For the process industries, technicians such as pipe fitters, welders etc. are ITI trained.

At present, there are 2,200 government run ITIs in India. In addition, there are 9,700 privately owned counterparts, known as Industrial Training Centers (ITC). Training is available in 126 trades (73 Engineering, 48 Non- Engineering and 5 exclusively for visually impaired) The training lasts for 1 to 2 years. At the end of the Institute training the students must undergo additional practical training for one or two years in his or her trade in a company. A National Trade Certificate is awarded to successful trainees. Having completed the academic and the practical training they may then apply to receive the national Council of Vocational Training Certificate.

The ITIs and the ITCs offer training in more than 130 trades. Only a small number of ITEs or ITCs offer training specific to the oil and chemical industries, Typical courses that may be offered are:

- Attendant Operator, Chemical Plant (AOCP),
- Instrument Mechanic, Chemical Plant,
- Laboratory Assistant Chemical Plant,
- Maintenance,
- Mechanical Chemical Plant,
- Fire Technology and Industrial Safety Management,
- Health, Safety and Environment

Information from Indian contract manufacturing and pharmaceutical intermediate companies is that typical plant operators have a BSc in chemistry, supervisors have a MSc in chemistry or a BSc in Engineering. Control room positions are typically filled by staff with engineering degrees. For all positions, additional process specific training is given beyond the requirements for a university level degree. Less experienced operators may be "apprenticed" to more experienced personnel.

The authors were unable to speak directly to any oil or petroleum companies which hired graduates from the training programs offered by the ITIs and ITCs. Therefore, it's not possible to draw any conclusions about the value of the oil and chemical industry courses offered by the ITIs and ITCs.

South Africa

A training program for chemical process operators was introduced in 2014 at the Nelson Mandela Metropolitan University in Port Elizabeth in South Africa's Eastern Cape province. It is the only program of its kind in South Africa. It was set up with the encouragement of PetroSA, the national oil company of South Africa. The program is sponsored by AECI, a South African explosives and specialty chemicals company and by BASF.

The process technology training program lasts for 2 ½ years and includes two years of class and laboratory study and six months working in an oil or chemical industry facility. The curriculum has been designed around a comprehensive profile for

a chemical process technician that provides for training in and across seven competencies: personal effectiveness, academic knowledge, professional skills, regulatory knowledge, technical skills, organizational skills and management competency.

Hands-on practical training includes training in the only operating pilot chemical production facility at a South African university. This provides for seamless integration into a real-life working chemical industry environment. Emphasis is placed on communication skills and teamwork in view of the critical nature of many of the tasks of the chemical process technician who work in production facilities.

Most students join the program immediately after completing their secondary education at a high school in South Africa. The success rate in obtaining a position in the chemical or oil industry for the student who completes the program is 70% to 80%. Students who graduate from the program also have the option of continuing their education with the goal of eventually obtaining a four-year degree in chemical or industrial engineering. Several students who are already working in industry have joined the program with the sponsorship of their employing company. When they complete the training program, they can return to work at their employer. To date, 46 students have completed the program and 58 are current students.

Lecturers at the program typically have an academical background although several have industry experience. Hiring lecturers with an industry background is challenging because there is not a significant chemical or oil industry presence in the Port Elizabeth area.

Australia

Australia is a major exporter of agricultural products, particularly wheat and wool, minerals such as iron-ore and gold, and energy in the form of coal and liquified natural gas. With the recent natural resources boom, there has not been a sufficient supply of competent workers. In addition, the work force is aging with workers in their 40s, 50, and 60s moving towards retirement. As a result, there is an ongoing need for qualified personnel in the natural resources arena (on-shore and off-shore oil exploration, chemicals manufacturing and mining). Safety in Australia is legislated within each individual state or territory, meaning that including the Commonwealth, there are nine different legal jurisdictions, each with slightly different requirements. For process safety, Australia operates under a safety case regime which is rigorously enforced by each jurisdiction.

Australia has a system of Technical and Further Education (TAFE) colleges which offers courses in most larger towns and cities at technical schools and community colleges. In addition, individuals and companies can be accredited as a Registered Training Organization and offer courses and modules of training.

There are several education levels for vocational training

- Certificate 1 is a basic qualification, necessarily linked to other simple vocational competencies,
- Certificate 2 is a trade-specific competency, that would be linked to other competencies to become a trade qualification,
- Certificate 3 is a trade qualification, wherein several competencies are brought together as a demonstrated trade,
- Certificate 4 demonstrates the person's qualification in a field of vocational education and training,
- Diploma,
- Advanced diploma.

Manufacturing Skills Australia is the current training package developer for the PMA08- Chemical, Hydrocarbons Training Package which details the technical competency requirements for process plant technician i.e. Certificate 2 to Advanced Diploma. These are recognized across all jurisdictions.

Because of the mining and natural resources boom in Western Australia it has a Center of Excellence specializing in process training – Australian Centre for Process Training (ACEPT) which is part of the Perth South Metropolitan TAFE. ACEPT offers course in process plant technology from Certificate 2 to Certificate 4, Diploma and Advanced Diploma.

Additional to this, the upstream industry established a Common Safety Training Programme (CSTP) and a Supervisor Safety Training Program (SSTP) to form a consistent safety introduction across all sites. This is supplemented by local training at the facility.

Observations and conclusions

There are no standardized approaches to recruitment and training within the chemicals and oil refining sectors around the world. It is very much 'horses for courses' which ensures flexibility but leaves the door open for a wide variation in the minimum skill set for process technicians and night time supervision. However, there are some common themes associated with having a Degree or Higher Degree in process engineering for oversight roles and a 'locally' defined or accepted normal level of technical qualification for all plant operational roles.

Leaving aside the National Service elements, the system in Singapore of a fully integrated secondary school through to technical qualification framework forms a useful benchmark of good practice. Oil refining and chemical manufacturing facilities are becoming more complex, with new advanced process controls being used in most facilities. There is continued pressure from communities and stakeholder groups for incident free operation of facilities. An incident at a chemical plant or an oil refinery can quickly cost a company very significant amounts of money, from lost production, lawsuits, rebuilding costs etc. Process technicians are at the front line of safe and efficient day to day operation. They need to well-educated and trained.

Encouragingly, process technician jobs in the oil and chemical industries are desirable and pay more than the industrial average. Academic studies have shown that companies can save training costs by hiring process technicians who have a two-year degree in chemical process technology (PTEC). The oil and chemical industries should move further in the direction of hiring process technicians who have a two-year associates degree in process technology. The oil and chemical industries and colleges and universities should collaborate in developing programs for candidates who wish to have a career in those industries. The oil and chemical industries and academia should carefully evaluate programs such as NAPTA and *petrochemworks*.

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