THE EMERGENCE OF THE DISCIPLINE OF PETROLEUM ENGINEERING:

AN INTERNATIONAL COMPARISON

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The worldwide petroleum industry had its beginnings in the United States in the mid-nineteenth century, but soon expanded into Russia in the 1870s and Asia and the Middle East soon after the turn of the century. Engineering practice with regard to the exploration, drilling, refining, and distribution of oil and its products was largely craft-based and *ad hoc* in the early years. It soon became apparent, however, that technical problems peculiar to this industry demanded more formal expertise.

This paper explores the emergence of the formal discipline of petroleum engineering, concentrating on developments in the United States, Great Britain, and Russia. It discusses the role of leading proponents of petroleum technology, such as Henry L. Doherty in the United States and Sir John Cadman in Britain, the beginnings of academic curricula and programmes in petroleum engineering, and the creation of discrete organisations of petroleum engineers.

Although the global petroleum industry originated in the United States in the mid-nineteenth century, its reach extended as entrepreneurs exploited new crude oil supplies in Russia in the 1870s and in Asia and the Middle East by the turn of the century. In the industry's early years, engineering practice with regard to the exploration, drilling, refining, and distribution of oil and its products was predominantly craft-based and *ad hoc*. In large part the sudden and rapid growth of this new economic activity explains this pattern. In the United States, crude oil production increased from only 2,000 barrels in 1859 to 4,800,000 barrels in 1869 and 5,350,000 barrels in 1871 (one barrel = 42 U.S. gallons).

In 1884, after a decade of development and the completion of the Baku to Tiflis railroad, some 553,000 barrels of Russian illuminating oil (kerosene) went to market. When compared to U.S. exports of approximately 10.3 million barrels that same year, this was a mere trickle, but the flow of Russian oil products into the world export trade soon became significant.[1]

In this wide open and competitive business, wasteful practices were very evident. In his *Special Report on the Petroleum of Pennsylvania* in 1874, geologist Henry Wrigley concluded that 'Without considering the question of blame or possibility of a remedy, it seems to be a fact that merits serious attention, that we have reaped this fine harvest of mineral wealth in a most reckless and wasteful manner'.[2] Contemporary observers continued to assert this view, perhaps summed up best in the official census of 1880 that described the production of petroleum in the United States as 'wasteful in the extreme'.[3] The opening of the Russian Baku fields by the Nobel and Rothschild interests after 1874 saw the continuation of similar practice. Petroleum flowed so readily in the Baku region that there seemed to be little concern for efficiency and conservation in the development of new fields. American visitors to Baku, themselves no paragons of conservation methods, commented in amazement at the inefficiency, sloppiness, and lack of care that Russian operators demonstrated.[4]

As the industry evolved, it became apparent that technical problems demanded more formal expertise. This paper will explore the early formation of the discipline of petroleum engineering, concentrating on developments in the United States, Great Britain, and, to a lesser extent, Russia. Although a latecomer, the birth of petroleum engineering coincided with a generalised desire among engineers to achieve professional status. The examination of one particular engineering profession at a crucial time in an industry's history will provide some insight into the international comparison of the engineering professions. The paper will then explore the relationship between petroleum engineers and a rising movement for engineering efficiency in the early twentieth century. It will focus on one case study in the early formulation of the science of reservoir engineering, emphasising the contributions of two industry leaders, the American Henry Doherty and the Englishman Sir John Cadman.

ORIGINS OF AN ENGINEERING DISCIPLINE: THE UNITED STATES

In his recent work on the social context of American practitioners, Edward Constant correctly describes the two meanings that have emerged for the term petroleum engineering. The first usage describes broadly any of the technical expertise associated with the production, transportation, or refining of crude oil and its products. In a more restricted meaning that is common today and associated with the formal discipline of petroleum engineering, the term refers to the specific engineering science associated with production or reservoir engineering (what Constant calls 'getting it out of the ground').[5] Petroleum engineering (PE) as a well-understood separate branch of engineering, is a relative newcomer, not achieving a discrete academic identity until well into the twentieth century. In today's spectrum of engineering specialities in the United States, it is not as old as chemical and industrial engineering, about the same age as aeronautical, and older than either nuclear or computer engineering.[6] In the formative years of the profession, however, the lines between fields were not so precise, and petroleum engineering would long retain its more generic meaning.

In the United States during the first decade of the century, increasing numbers of college graduates from established courses in chemistry, geology, and engineering met the growing need for scientists and engineers in the industry. Soon, however, there arose a perceived need for technical training specifically geared to the petroleum industry. Early programmes appeared first within mining engineering curricula. For example, in 1907 graduates of the Stanford Department of Mining and Geology played a leading role in the new California oil industry, and in 1910 the University of Pittsburgh began offering courses in oil and gas technology and law. Pittsburgh established separate degrees in petroleum geology and petroleum engineering in 1912 that many cite as the first offered in any university in the world. The University of Birmingham, which established a programme in Britain that same year, may legitimately challenge this claim, but since the American term began in September and the British term in October, perhaps Pittsburgh deserves credit as 'first.' Other American universities soon followed the Pittsburgh lead, including the University of California and Stanford, 1915; West Virginia University, 1916; the Colorado School of Mines, 1921; Missouri School of Mines, 1922; the University of Kansas, 1924; Pennsylvania State College, the University of Texas, the University of Tulsa, 1928; and the University of Southern California and Texas A&M, 1929.[7]

A series of related and important non-academic events accompanied these early curricular developments. In 1913 the American Institute of Mining Engineers (AIME) created its Oil and Gas Committee, which later evolved into the Oil and Gas Division, and more recently, the Society of Petroleum Engineers (SPE). This organization represented the first open forum in the United States for the presentation and publication of papers dealing with the geological and engineering phases of the oil industry.[8] The U.S. Bureau of Mines, created in 1910 within the Department of the Interior to promote conservation and safety, established its Petroleum and Natural Gas Division in 1914. The Division opened a designated petroleum experiment station in Bartlesville, Oklahoma in 1918 and undertook some of the first systematic scientific and engineering research in the industry. Located in the heart of the Midcontinent oil boom of the early twentieth century, this facility, under various names, would remain at the centre of federal government research in petroleum technology up into the 1980s. Bartlesville personnel provided scientific and technical research information for the 'independent' oil company as distinguished from the large, vertically integrated firms which typically had their own research departments. The Bulletins and other publications of the Oil and Natural Gas Division represent an important chronicle of state-of-the art knowledge, particularly on reservoir engineering and production related problems. Both the AIME and the Bureau of Mines continued to play important interactive roles with the development of academic programmes in petroleum engineering.[9]

In 1916, businessman Henry L. Doherty initiated another important development outside the academy. He founded the Doherty Training School at the offices of his Empire Gas & Fuel Company (later the Cities Service Oil Company), also in Bartlesville, Oklahoma. Doherty, a pioneer in efforts to introduce scientific principles into oil pool management, hired young college graduates from mechanical, electrical, civil, and chemical engineering as well as from geology for his firm. These "junior engineers" would then train in specific applied areas relevant to the oil and gas business, of which Doherty was a major Mid-continent operator.[10] The Doherty Training School became a prototype for other in-house programmes begun by private industry.

The report of a 1926 AIME-sponsored Round Table on 'Petroleum Engineering Educational Problems' divided the increasingly specialized field into four headings: geological engineering, production engineering, transportation engineering, and refining engineering. Curricula and departments had become formalized by the early 1930s, with at least fifteen PE programmes in place. Some of these were affiliated with geology, some with mining engineering, and some with mechanical engineering departments. Others were completely separate degree-granting departments. These programmes began to centre increasingly on drilling and production operations, with a strong supporting role for geology. During the roughly twenty-five year period after 1930 the petroleum engineering curriculum firmly established itself as a separate field in the United States, with reservoir engineering and petroleum recovery methods as a central focus. Graduate and research programmes began to appear within the PE departments, and universities within oil-producing regions assumed an active role in furthering the study of petroleum technology. Beginning in the 1920s with the formation of the powerful trade association, the American Petroleum Institute (API), a great deal of financial support had begun to flow into university departments from the Institute's special research fund.[11]

EARLY DEVELOPMENTS IN BRITAIN AND RUSSIA

The University of Birmingham offered the first discrete petroleum course in Britain in 1912, the same year that the University of Pittsburgh had established its degree programme in the United States. John Cadman, appointed Professor of Mining at Birmingham in 1908, was the principal founder and supporter of this undergraduate course in 'Petroleum Technology' until he left the University in 1920. That year several large British oil companies liberally endowed the well-established Birmingham programme with funds. In 1913 noted petroleum expert Boverton Redwood established a curriculum in petroleum engineering at the Royal School of Mines in London (part of the new Imperial College of Science and Technology after 1907). These were the only two university degree programmes to appear in Britain by the early 1930s, each of them enrolling approximately forty students. Because of its strong industry connections, particularly with the Anglo-Persian Petroleum Company with whom Cadman later became associated, Birmingham's programme remained the best known in this period. Its undergraduate course catered to the needs of four groups of students: 1) oil field engineers and managers; 2) refinery managers, chemists, and chemical engineers; 3) practising and consulting petroleum technologists; and 4) exploitation geologists. A fifth group of students who wished to specialize in petroleum geology took only a few specialized courses in petroleum technology. Their curriculum differed little from standard geology programmes at Cambridge or Oxford.[12]

An American AIME observer in 1931 concluded that 'the offering at Birmingham would be considerably more valuable to the student who planned to enter the refinery than it would to one entering production work'.[13] But since the Royal School of Mines geology department administered the London-based programme in petroleum technology, its emphasis was quite different from that at Birmingham. Even though the curriculum required work on the chemical and refinery side, there was much more emphasis on crude oil production. In this respect the Imperial College programme had come more to resemble what American PE programmes had become by the early 1930s.[14]

Related developments in petroleum technology outside British higher education paralleled those in the United States. A committee on petroleum originated within the Institution of Mining and Metallurgy, a professional association that had been founded in 1892. This institution still sponsors an annual conference devoted to papers on metallurgy, geology, mining engineering, and petroleum engineering. In 1913 the current Institute of Petroleum was formed in London to promote research and publication in the more narrowly defined petroleum field. The Fuel Research Board, a government organization analogous to the U.S. Bureau of Mines, appeared initially in the U.K. to conduct research related to the coal industry, but had begun to work in petroleum-related areas around the time of World War I.[15] The British oil industry also took a hand in promoting petroleum technology and education through its own private research laboratories. Anglo-Persian had created its Sunbury-on-Thames laboratory in 1916, the same year that Henry Doherty had established his training school in

Oklahoma. Anglo-Persian along with Anglo-American and Royal Dutch Shell, used their testing and research laboratories as training grounds for chemists and refinery engineers. In addition, research conducted at the University of Birmingham and Imperial College, together with laboratories at other British universities, began to perform a substantial amount of work instigated and financially supported by individual firms in the oil industry. A broad non-proprietary and industry-backed programme of research support like the United States API effort did not emerge, however.[16]

There appear to have been no specially organized petroleum courses on the continent before 1930. In Russia, Poland, and Romania, however, petroleum subjects had become incorporated into other curricula at the universities. In countries such as Russia and Romania where oil fields existed, for example, petroleum geology resided in the geology curriculum. In a similar vein, courses in the natural hydrocarbons and their treatment could be found in the university chemistry curricula of producing nations.[17]

The fate of Russian programmes in petroleum engineering appears linked to the broader story of technical education in that country. A limited but strong foundation in engineering education based on the French model had been established in the first half of the nineteenth century, and mining engineering was part of it. In the second half of the century a significant expansion of programmes accompanying a rise in industrial activity led to the creation of new technical colleges to supplement more established institutions. Polytechnic institutes were set up in Kiev and Warsaw (1898), St. Petersburg (1902) and Novocherkassk (1906), with the St. Petersburg school exerting a particularly strong influence on Russian engineering education. The impact of the war and the Bolshevik revolution would pose a serious setback to Soviet technical education programmes. According to the most cited expert on this subject, Stephen Timoshenko, it was not until the 1930s that the failure of Bolshevik educational reforms led to a return to largely pre-revolutionary technical curricula. The Soviet model then became one of highly specialized faculties, petroleum subjects being taught within mining departments such as "mining-chemical" and "mining-geological."[18]

In his comparative study of the evolution of engineering education in France, Germany, Britain, and the U.S.A., Peter

Lundgreen notes that the two continental nations in his sample early developed programmes for the academic schooling of engineers ('school culture') as contrasted with an Anglo-American tradition of practical apprentice training ('shop culture'). The Russian experience generally conformed with Lundgreen's first case because of the strong French influence on its engineering courses of study. But Lundgreen further argues that an international convergence in engineering education began to take place around 1870. He interprets a final victory for the 'school culture' over the 'shop culture', as a new dominance of what he calls the 'employed techno-bureaucrat' over other occupations, and 'the seizure of ever-growing fields of activity, whether defined by new disciplines (electrical technology, electronics) or by specialization along the lines of new products (automobiles, aircraft, etc.)'.[19]

Petroleum engineering fits nicely into this analysis. PE training programmes arose in response to demands created by a new industry and products, and industry has had a very significant role in shaping the nature of technical education up to the present day. One deviation from Lundgreen's view of the triumph of the 'school culture', however, is that hands-on apprentice type training has remained an important part of the formal education of petroleum engineers in both Britain and the United States.[20]

PETROLEUM ENGINEERS AND INDUSTRIAL EFFICIENCY: THE CASE OF OIL FIELD UNITIZATION

Perhaps more than other American practitioners during the twentieth century, petroleum engineers have conformed to the view of the engineering profession depicted in David F. Noble's provocative study of technology and the rise of corporate capitalism. Noble could be describing this group when he writes,

> Thus, from the outset, they [professional engineers] hardly proceeded according to the dictates of some logically consistent 'technical reason,' blindly advancing the frontiers of human enterprise, but rather informed their work with the historical imperatives of corporate growth, stability, and control: as their technology progressed, so too did the science-based industrial corporations which they served.[21]

Compare these words with the stated aims of the Doherty Training School that called for educated men 'who when trained can help to protect our investments by proper construction and operation; who can aid in the development and extension of our markets through rendering the best of service and through the most economical utilization of resources.'[22]

This desire to achieve efficiency and wise utilisation of resources in large measure defined the discipline of petroleum engineering in its formative period. The fickle nature of the oil business in the United States, with fluctuating glut and scarcity and accompanying price disequilibrium, was a constant problem for the businessman. Initially, there was very little technical understanding of the functioning of underground oil reservoirs, and landowners and operators soon realized that someone on an adjacent property could drain oil from beneath their own land unless they drilled for it first. This situation stimulated rapid exploitation of pools and resulted in just as rapid depletion. When individuals sought legal protection of their property rights through the courts, judges hammered out a workable doctrine in a series of decisions in Pennsylvania, the first major oil-producing state. First citing English common law as it pertained to water rights (Acton v. Blundell, 1843), the courts offered an analogy between underground oil and percolating waters to argue that each property owner had unlimited rights to draw oil from his own land. A Pennsylvania Supreme Court decision in 1889 (Westmoreland Natural Gas Co. v. DeWitt) crystallized the notion by extending the analogy to wild game. Just as English law allowed a property owner the right to capture game that he had lured onto his land, so could he also 'capture' oil that had migrated under his property (at the time it was the general belief that oil flowed in underground rivers). These rulings encouraged a competitive rush to exploit each oil discovery before others depleted the pool, a wasteful practice that continued as the American oil frontier moved westward from Pennsylvania, Ohio, Indiana, and Michigan to Texas, California and the Mid-continent.[23]

In the United States after World War I, Henry L. Doherty became the most outspoken advocate of replacing the "law of capture" with a more scientific and efficient approach termed "unitization" or the unit management oil fields. Under this plan, all lease and royalty holders would pool their interests and drilling could proceed in an orderly manner, with the number of wells apportioned by percentage ownership in the field. Operators would drill fewer wells and crude oil production could flow at a controlled rate. One could utilize natural gas obtained with the oil or return it to the producing zone under pressure rather than flare or vent it into the atmosphere. The technical key to this new principle of reservoir engineering was the concept that all recoverable oil in its undisturbed state contains gas in solution, and that this solution has lower viscosity, specific gravity, and surface tension than gas-free oil. The maintenance of gas pressure would assure the maximum long-term recovery of oil from the pool. Thus, the political and legal programme of unitization rested on an essential engineering principle.[24]

Doherty had no formal training in science or engineering himself, but, as demonstrated above, he had been an early supporter of petroleum technology. In addition to founding his Training School in 1916, he was instrumental in locating the Bureau of Mines Experiment Station in Bartlesville in 1918, and he created his own research experiment station within the Cities Service operation. Working first through the American Petroleum Institute and then through the Federal government directly in the 1920s, Doherty strove hard to obtain mandatory oil field unitization. In 1921 he hired C.E. Beecher, a civil engineering graduate from Stanford and one of the leading reservoir specialists in the country, away from the Bartlesville Experiment station to direct Cities Service research on oil field recovery.[25] This work resulted in a seminal paper on gas pressure ratios in oil pools written by Beecher and I.B. Parkhurst.[26] These technical findings rather than Doherty's political posturing ultimately convinced industry leadership of the need to change the nature of oil pool management.

Final vindication for Doherty would not come until the East Texas flush strikes of 1930–31 convinced even the most traditional industry leadership that some degree of wider co-operation was necessary. Unfortunately, ten-cent-a barrel East Texas oil demonstrated that the problem of oil field overproduction had gone far beyond the abilities of unit operations to control the flow. The New Deal decade in the United States ushered in wellhead prorationing, whereby government authority limited the number of barrels that could be pumped from each well, as a more direct way to curtail the Texas and Oklahoma glut. Petroleum engineers from the Bureau of Mines and the industry would become key players in establishing the technical basis for this new legal approach, a subject that I and others have discussed elsewhere.[27]

In the United States the technical logic behind unit management of oil pools ran directly into conflict with the competitive nature of an industry that had been weaned on the principle of 'law of capture'. In the case of British petroleum engineering, however, the fact that in most cases there was only a single leaseholder in a given foreign field permitted greater success in the 1920s. The experiences of Anglo-Persian in their operation of the huge Masjid I-Suleiman field in south west Iran illustrates this nicely. Field manager R.R. Thompson, working closely with geologists, in 1920 developed a production strategy of putting oil bearing territory under a single management. Elsewhere, argued Thompson, 'the sole idea of the various interested Companies has been an anxiety to tap the oil horizon before their rivals, regardless of the damage done to the oil-bearing strata by faulty drilling to the detriment of the prolonged productive capacity of the field'.[28]

Concluding independently that retention of gas pressure was essential for the long-term development of the pool and that over drilling was detrimental to this, Thompson initiated a new approach that would establish Anglo-Persian as a world industry leader in the efficient exploitation of petroleum reservoirs. Under Sir John Cadman's leadership, Anglo-Persian would embrace these progressive and scientifically sound practices. In addition to his Professorship of Mining at Birmingham, Cadman was a key technical adviser on petroleum matters to the British government, both before and during the First World War. He joined Anglo-Persian in 1922 as deputy chairman, and in 1927 rose to the chairmanship upon the retirement of Charles Greenway. Cadman placed improvement of the firm's technical practices high on his agenda, and he was instrumental in bringing Anglo-Persian into its position of world technological leadership. Cadman had immediately recognized the importance of an internal 1923 paper on 'Gas Pressure Problems on Maidan I-Naftun Field with reference to the Conservation of Supplies and Future Drilling' written by engineer D. Comins and geologist E.W. Scofield. He ordered these principles to be implemented in the field and insisted that efficient conservation practice be continued in future exploration and development.[29]

The state of technological progress in Russian oil field management during this period is less clear. Royal Dutch-Shell had purchased Baku producing properties held by the Rothschilds prior to World War I, but the Bolsheviks nationalized these and all other foreign holdings in 1918. Royal-Dutch Shell and Standard Oil (New Jersey) carried on negotiations throughout the early 1920s to regain a foothold in these properties, but failed. Standard, desirous of obtaining foreign leases, had negotiated to purchase one half of the Nobel brothers' Petroleum Producing Company in 1920, but found its entry blocked by the Kremlin. There were Western attempts to boycott Russian oil in the 1920s, but the Soviets had little difficulty in selling surplus product on world markets.[30]

The evidence suggests that Soviet oil field practice remained relatively inefficient and wasteful under the Soviet regime. With the introduction of more formal economic planning under Stalin in the 1930s, it would seem that Russian petroleum engineers were in a good position to impose latest technological practice. With relatively little concern about bottom-line profit and price fluctuations, Soviet engineers and managers should have been able to concentrate on maximizing oil production over the longest period of time. But if Soviet petroleum officials were not bound to make a profit, they were under pressure to fulfil five-year plan output targets. Oil drillers tended to increase petroleum production in the short run to earn credit for exceeding quotas rather than to plan for some undefined future.[31]

CONCLUSIONS

By the late twentieth century the discipline of petroleum engineering has become recognized in the United States, Britain, and Russia as a distinct field of training and technical qualification. The scientific approach to reservoir management took on even greater meaning when the world had to face the prospect of petroleum scarcity during the 'energy crisis' of the 1970s. Wise and efficient utilisation of petroleum reserves became not just an economic issue, but a matter of national security. Yet, in the 1990s we are again awash in a sea of oil and immediate scarcity of supply appears of little political concern. Anyone who has studied the history of the oil industry understands that the cyclical pattern of alternate glut and scarcity has been its most dominant theme, and that shortages are again lurking around the corner.

This historical pattern has had a direct impact on jobs for petroleum engineers. Amidst periods of growth and expansion of the industry there have been critical shortages of trained personnel. During such a time in the 1950s, for example, there was great concern in Britain about the lack of qualified individuals. At a 1957 symposium on "Engineering Progress and the Oil Industry" sponsored by the Institute of Petroleum at Folkstone, delegates widely discussed this issue.[32] The United States situation today illustrates the other side of the problem, as declining enrolments in PE programmes, the elimination of some such programmes, and a generally dismal job market for petroleum engineers seriously threatens the profession.[33] Russia appears to be experiencing some different problems. Because of the importance of petroleum exports in earning hard currency in both the Soviet and the post-Soviet eras, it would behoove that industry to institute the most efficient and technologically sound strategies of exploitation. Yet although Russian petroleum engineers have made signal contributions in research and publication, an immense gap between elite research and industry practice continues to exist.[34]

One thing can be predicted with certainty. The world petroleum industry will continue to be critically important well into the twenty-first century, and economies will once again face the vicissitudes of declining supply and uncertain price structure. The skill of the petroleum engineer will again be needed to shepherd us through a period of scarcity and probable transition to a greater reliance on renewable forms of energy.

NOTES

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