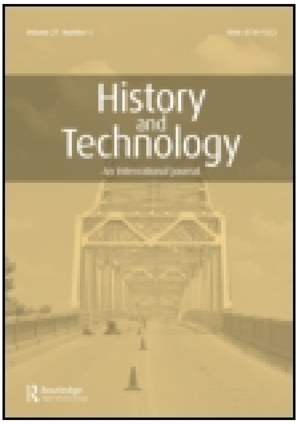


History and Technology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ghat20

# Security and the shaping of identity for nuclear specialists

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Available online: 18 Jul 2011

To cite this article: Sean F. Johnston (2011): Security and the shaping of identity for nuclear specialists, History and Technology, 27:2, 123-153

To link to this article: http://dx.doi.org/10.1080/07341512.2011.573265

*History and Technology*
Vol. 27, No. 2, June 2011, 123–153

Routledge
Taylor & Francis Group

# Security and the shaping of identity for nuclear specialists

Sean F. Johnston*

Atomic energy developed from 1940 as a subject shrouded in secrecy. Identified successively as a crucial element in military strategy, national status and export aspirations, the research and development of atomic piles (nuclear chain-reactors) were nurtured at isolated installations. Like monastic orders, new national laboratories managed their specialist workers in occupational environments that were simultaneously cosseted and constrained, defining regional variants of a new state-managed discipline: reactor technology. This paper discusses the significance of security in defining the new subject in the USA, UK and Canada – wartime allies with similar political traditions but distinct trajectories in this field during the Cold War. The intellectual borders and content of the subject developed differently in each country, shaped under the umbrella of secrecy by disparate clusters of expertise, industrial traditions, and national goals. The nascent cadre was contained until the mid 1950s by classified publications and state-sponsored specialist courses. The early context of high security filtered its members and capped enduringly both their professional aspirations and public engagement.

**Keywords:** nuclear engineer; security; secrecy; identity; profession; atomic energy



## Introduction

The historiography of the nuclear age covers a broad terrain, well mapped in some areas but sparsely explored in others.[1] This paper focuses on the emergence of the technical specialists who developed atomic energy, and particularly reactor technology, over the quarter century that began with the Second World War. I compare the evolution of the field in the USA, UK and Canada, because as wartime allies and nations with similar political traditions they highlight the similarities and differences of this specialist field, so distinctive of the Cold War. Moreover, each of these countries later played a role in internationalizing their distinct models of nuclear engineering via training courses and the export of reactor technologies.

The restriction of knowledge was central to the early definition of this new breed. Nuclear workers evolved as an amalgam of specialists from the 1940s, shaped by the exigencies of program secrecy as much as by disciplinary refinement. But despite the military origins, postwar atomic energy fostered endeavours quite distinct from bomb-making, inspiring physicists, chemists and a rapidly growing contingent of engineers and technicians to explore deeper scientific and technical questions alongside inchoate hopes of improving their societies by harnessing the atom. These divergent concerns bred new kinds of specialists. Only a fraction of them – those vocal and visible members of the 'atomic scientists movement' who actively promoted internationalism and progressive ideals during the postwar years – have been the focus of much scholarly attention, as have contemporary weapons scientists.[2]

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ISSN 0734-1512 print/ISSN 1477-2620 online

DOI: 10.1080/07341512.2011.573265
http://www.informaworld.com

While such groups arguably could be represented as a technical priesthood, they were gradually overtaken by another body of specialists more akin to acolytes. The subjects of the present paper are the cousins of the more studied scientists: the engineers, technicians and skilled workers responsible for reactor and separations technologies, who have remained relatively voiceless and unexamined.[3] Their occupations ranged from the design of reactors and radio-chemical processes (expertise dubbed *nucleonics* by some and *nuclear engineering* more widely) to production and maintenance work by lower-grade specialists.[4] Although differences in occupational categories makes enumeration difficult, their numbers amounted to several thousand professionals and considerably more skilled workers in North America and the UK by the end of the 1950s, when nuclear power was becoming their focus and engineers were beginning to overtake scientists.[5]

These nuclear specialists worked at a handful of wartime government facilities, at postwar national laboratories and production facilities that succeeded them, and at industrial companies contracted to design, build and operate those facilities. Those employed by universities generally had close links with the national laboratories, which concentrated the material resources and expert labor. Their goals bypassed bomb making – and indeed in Canada eschewed it – by exploring the potential for nuclear reactors and the myriad material, chemical, mechanical and thermal factors that determined how they were engineered. As their growing know-how had strategic importance variously for military strategy, national status and export aspirations, their governments sought to maintain their head start in the field by restricting the circulation of knowledge.

As this suggests, the role of the state was prominent in these nascent technical professions, with security playing a key role in shaping their evolution despite their early divergence from military objectives. Secrecy, particularly in the US context and during the Cold War, has been the focus of studies by sociologist Edward Shils in the mid 1950s, and Daniel Moynihan from the historical perspective of the post-Soviet period. Both distinguished *functional* secrecy – pragmatically necessary control of sensitive knowledge – from *symbolic* secrecy, identified as an ideological extremism having deleterious effects for a nation and, by extension, to social groups within it.[6] The nuclear context of security, which amplified and routinized such symbolic secrecy, has been addressed insightfully by research from the top–down perspective of policy studies,[7] but seldom in relation to its influence on technical identity, i.e. from the grassroots. Two exceptions are Hugh Gusterson's anthropological study of contemporary nuclear weapons scientists, which explores the effects of secrecy on employees of the Livermore National lab, and Joseph Masco's complementary account of present-day Los Alamos, also dedicated to weapons development.[8] This paper, however, discusses the evolution of measures intended to protect non-military expertise in atomic energy during its first quarter-century, and specifically their influence on the emergence of working identities for a variety of nuclear specialists in the first three countries that supported them – the UK, USA and Canada. Comparison of the outcomes provides an unusual opportunity to assess the role of national context in disciplinary development, and the degree to which the insulating effects of secrecy caused these pockets of expertise to grow in distinct varieties. The three national programs, particularly during the decade after the Second World War, amounted to separate and privileged experiments in the creation of a new intellectual field.[9]

I argue that security was significant to technical identity in five respects: nuclear specialists were managed in new isolated environments; their intellectual products were classified for restricted dissemination; their political activities and labour representations were scrutinized; their collective identity was shaped by pre-existing institutional and industrial affiliations; and their training, job categories and disciplinary labels were assigned largely by their respective governments. Each of these aspects of working life was dissimilar to prevailing pre-war scientific and industrial contexts.

Security operated in three spatial domains: the international secrecy operating between nation-states, the domestic secrecy between different atomic energy sites and the interactional secrecy required of individual nuclear workers. Central to each was intellectual isolation. The term *cloister* evokes an analogy identifying atomic energy establishments as akin to monastic sites, and the association of their dedicated workers with enclosed religious orders. Like mediaeval monasteries, wartime and postwar national laboratories in the USA, UK and Canada promoted distinct regional variations; they were not founded primarily with economic motivations, but on locally nuanced and isolated intellectual foundations; they combined idealism with pragmatic duties; and, they served a strong central authority. Although a limited analogy, it suggests the peculiar environments for nuclear workers during their first 25 years, and the combination of personal, institutional and intellectual containment on their working lives.

While this paper focuses on nuclear specialists, it is important to sketch and periodize the shifting regulatory framework in which they developed. The intent is not to nuance the details of national policies, but to illustrate their rather blunt yet profound effects for the careers of nascent technical specialists. Three distinct temporal regimes of security are relevant to the discussion, as suggested by the brief chronology listed in Table 1. The first was the wartime secrecy imposed by the Manhattan Project and precursor committees in the USA and UK. The second comprised nearly a decade after the 1946 McMahon Act in the USA, when the circulation of knowledge between the former allies was limited and during which security measures ebbed and flowed in response to perceived foreign and domestic threats of espionage in each country. A third, considerably more relaxed, period followed the late 1953 'Atoms for Peace' initiative of the Eisenhower administration and especially its consolidation by the subsequent UN-sponsored Conference on the Peaceful Uses of Atomic Energy in Geneva in August 1955.

In brief, then, the wartime Manhattan Project secrecy, followed by a decade of selective and varying security measures, was replaced in turn by a cautious openness from the mid 1950s. These three security regimes did not evolve towards complete transparency, however: endemic national security concerns gave way to rising commercial secrecy. In short, the enduring nature of technical specialists in the nuclear field owed much to their cloistered origins.



## Wartime containment and gestation

The initial regime of security was instigated by the Manhattan Project, during which the USA, UK and Canada had on-again, off-again collaboration. The wartime investigations of atomic energy were undertaken in environments appropriate to a strategically valuable military secret, and management focused largely on restricting and channeling the flow of information about the very existence of the project and its technological trajectory. The principal feature of security, from the standpoint of the technical participants, was intellectual isolation within and between a handful of sites developing reactor and separation technology. These included the 'Metallurgical Laboratory' at the University of Chicago, soon moved to the nearby Argonne Forest, which originated studies of chain-reactor design and oversaw their implementation; the Clinton Laboratory at Oak Ridge, Tennessee, responsible for the pilot plant production reactor and developing plutonium separation processes; Hanford, in Washington state, the site of three plutonium production reactors; the Montreal Laboratory, Quebec, first site of the Anglo-Canadian project, devel-

Table 1. Initiatives and events relating to atomic energy secrecy.

| Year | USA | UK | Canada |
|---|---|---|---|
| Oct. 1939 | Briggs Advisory Committee on Uranium formed | | |
| Apr. 1940 | | MAUD Committee formed | |
| Dec. 1940 | | | National Research Council experiments |
| Jul. 1941 | S-1 Uranium Committee formed | | |
| 15 Jul. 1941 | | MAUD reports distributed; Tube Alloys Project begun | |
| Aug. 1942 | Manhattan Engineering District formed | | |
| Dec. 1942 | | | Montreal Lab formed |
| Aug. 1943 | Quebec Agreement | Quebec Agreement | Quebec Agreement |
| Sep. 1945 | Smyth Report | | |
| 1946 | McMahon Atomic Energy Act | | |
| Mar. 1946 | | Alan Nunn May spy case | |
| Aug. 1946 | US Atomic Energy Commission formed | | |
| Feb. 1950 | | Klaus Fuchs spy case | |
| Aug. 1950 | | Bruno Pontecorvo spy case | |
| Sep. 1950 | McCarran Internal Security Act | | |
| Apr. 1952 | | | Atomic Energy of Canada Ltd formed |
| Dec. 1952 | McCarran-Walter Immigration and Nationality Act | | |
| Dec. 1953 | Atoms for Peace speech | | |
| 1954 | Atomic Energy Act revised | UK Atomic Energy Authority formed | |
| Aug. 1955 | International Conference on the Peaceful Uses of Atomic Energy (Geneva, Switzerland) | International Conference on the Peaceful Uses of Atomic Energy (Geneva, Switzerland) | International Conference on the Peaceful Uses of Atomic Energy (Geneva, Switzerland) |
| Sep. 1958 | Second Geneva Conference on the Peaceful Uses of Atomic Energy | Second Geneva Conference on the Peaceful Uses of Atomic Energy | Second Geneva Conference on the Peaceful Uses of Atomic Energy |

oping the theory of heavy-water reactors; and, Chalk River, Ontario, site of the first Canadian reactor.

The chemical company Du Pont de Nemours, responsible for the Manhattan Project reactor program from late 1942, had implemented high security for its sites, working groups and individuals. Security measures largely separated design, construction and operational workers, restricting the information given to each group. Du Pont managers, long familiar with military security on other contracts, nevertheless disparaged the effects of segregation for this rapidly evolving field:

> Stringent security measures have governed all research, design, procurement, construction and operation procedure in order that the utmost secrecy may be maintained . . . . Personnel has had to be divided into groups each possessing only such information as is necessary for its own use in connection with its own part of the work. Engineers and supervisors have had to be told what must be done but not why, stifling to a major extent the independence of thought and critical analysis of problems ordinarily considered essential to efficient prosecution of the work.[10]

Opposing this compartmentalization was the necessity of making quite complete information available to a large group about the pile operation processes so that they 'could contribute satisfactorily to the success of the operation and could provide adequately for the safety of the operating employees and the avoidance of catastrophe.'[11] In an entirely untested engineering domain in which the dangers of intense radiation and potential explosion could not be estimated, the management militated against secrecy.[12] As an anodyne Du Pont summary put it, 'all of this had to be accomplished without arousing undue alarm in the minds of employees which would result in lowered efficiency or resignations.'[13]

Contrasting this need to reveal operational information to a wide selection of employees, administrators noted the vulnerability of the Hanford plutonium-producing reactors to sabotage or enemy action. As the first of them approached completion in July 1944, Hanford organized a Protection Department responsible for guarding, patrols, a site police force and investigations. Within eight months, its personnel exceeded that of the Operating Department responsible for reactor operations.[14] This pattern of surveillance was to become the norm.

Despite such restraints, the barriers could also provide environments in which to nurture new specialisms. As Peter Hales has noted in his cultural geography of the wartime sites, compartmentalization 'was a means to redesignate scientists and engineers as workers,' providing not just adequate security from inadvertent leaks but also efficiency.[15] Such subordination could also oppose existing hierarchies, and encourage more equitable cooperation between members. For example, at the Montreal Laboratory, the principal Anglo-Canadian nexus during 1943–4, participants found that the work required new and unfamiliar alliances between fundamental science and engineering, with engineers unconventionally taking the lead. As Head of Engineering Ronald E. Newell put it, 'this meant development of a completely new branch of engineering . . . . A great deal of new knowledge had to be acquired by the engineers and to some extent this has also applied to the theoretical and experimental physics sections and the chemistry section.'[16] The confined environment encouraged interdisciplinary exploration.

Such merging of scientific and engineering cultures was amenable for the Canadian participants drawn principally from the National Research Council and for the members of the British contingent seconded from Imperial Chemical Industries (ICI), both of which had close associations between engineers and scientists, but there was a hesitancy for the Montreal Lab scientific staff to merge in this interdisciplinary work.[17] Absorbed in particular tasks and starved of material resources to build a reactor, the members of the Montreal theoretical group tended to collaborate little with their engineering colleagues.[18] Segregation could provide a reassuring familiarity to some participants drawn into this unfamiliar style of research, however. Indeed, as one of the Canadian scientists recalled, 'Secrecy is the main fetish in the wartime military culture . . . . It was science in a closet. So we worked more or less in our separate corners. Under stress, we could not afford the luxury of seeing the broad picture, and became technicians in our separate cells.'[19]

This local containment was complemented by segregation from important aspects of the American project, a factor that promoted disciplinary divergence. The reactors for plutonium generation in Hanford, Washington remained off-limits to the Anglo-Canadian participants. The Canadian contingent included European participants judged to have dubious political allegiances, and the British among them – many of whom were seconded from ICI – were distrusted by US administrators for potential commercial espionage.[20] The Montreal-based workers had frustratingly little contact with their US counterparts until late 1943, during which time US expertise had developed rapidly. Without adequate supplies of uranium, graphite or heavy water essential for a reactor, and isolated from experimental findings by their US colleagues, workers at the Montreal Laboratory consequently developed a local Canadian variant of nuclear knowledge, devoting most of their effort to relatively sophisticated theoretical studies of heavy-water based reactor design.[21]

Similarly, technologies of separating plutonium from spent uranium fuel were closely guarded by their US counterparts. When the Montreal Laboratory staff was transferred to the new Chalk River facility in southern Ontario in late 1944, the criticism of US security requirements grew. An unsigned memo from one of the senior Chalk River staff complained:

> The morale [of our chemical engineers] has always been adversely affected by the lack of exchange of information. We have been forced to do work which we know has been done already . . . . The result has been that we have been obliged with a group of about 40 men to do what the Americans did with several thousand.[22]

As with proficiency in reactor technology, then, a distinct variant of nuclear chemical engineering was developing on each side of the border.

Security inhibited and became ingrained for many participants. The Manhattan Project scrutinized the activities of the Anglo-Canadian members even beyond the USA. When General Leslie Groves ruled that French contributors must leave Chalk River at the end of the war, one asked meekly for 'clear cut indications as to the nature and extent of the secrecy regulations to which I am still committed,' and what he would be able to take to the new French Commissariat à l'Énergie Atomique.[23] Those who had left the Anglo-Canadian project to return to France instituted similar security consciousness there. Key participant Lew Kowarski reported that 'Châtillon has its guards, as you in Brookhaven have yours; we are responsible for some of the secrets and our people are bound by certain, not very explicit but very binding, secrecy rules.'[24] What had been understood as sensible wartime security precautions for nuclear engineering were thus straightforwardly exported to other contexts. This combination of administratively decreed and personally adopted segregation helped to create proto-professions along clearer national lines.

## The postwar cloister

As suggested by the postwar French excommunication and adoption of security apparatus, some of the features of wartime security – segregated environments, cosseted isolation and careful monitoring of safety procedures – were amplified over the following decade to manage new perceived threats. Other conditions important in shaping technical identity, notably the filtering and categorization of personnel, developed in distinct national contexts.

A US cable immediately after the Japanese bombings defined postwar American censorship policy, which capped not only bomb-making expertise, but the broader and more fragile field of nuclear engineering. The policy censored dissemination of processes, formulas and mechanics; characteristics and quality of production materials; and, information on the relative importance of various methods and plants.[25] In the light of wider political factors, NRC Director C.J. Mackenzie and physicist John Cockcroft, responsible for the wartime Anglo-Canadian project, had little option but to recommend that Canada and the UK follow the same policy. Nevertheless, the barriers were permeable to varying degrees. While key US sites remained off-limits to UK and Canadian engineers and scientists, a US liaison officer remained based at the Montreal Laboratory and Chalk River.[26]

At war's end the initial mood of participants in all three countries was to declassify much of their new knowledge, based on scientific norms of openness and on the perceived potential for international benefit. The 1945 Smyth report consequently divulged important aspects of atomic energy science and technology.[27] For the first time, the less senior engineers, technicians and workers – like the general public – learned the purpose of the Manhattan Project sites and the nature of their work. The first postwar US legislation, Senator Brien McMahon's Atomic Energy bill, was drafted with further dissemination in mind, but within a year had mutated to control nuclear information. The Atomic Energy Act excluded Britain and Canada from any further collaboration on atomic energy and conceived national laboratories for US nuclear research. The subsequent roles of governments in linking 'big science' to national goals are well known.[28] In the USA and UK, atomic weapons programs were planned and implemented. There and in Canada, atomic energy – broadly conceived – was pursued at a handful of well-funded research centers.

Security provided a common framework and cage for the postwar field. It had clear aims: to protect secrets of military value, particularly from domestic and foreign communist espionage; to isolate the public from the potential dangers of radioactivity; and, to sustain the hard-won technological advance of the wartime work for other national or commercial advantage. Because of this, Canadian research – even though eschewing military applications – absorbed many of the security attributes of the US and British sites. For all three countries, security had knock-on effects for the creation of a cadre of nuclear engineers. Edward Shils observed that secrecy is a means of controlling suspected conspiracies.[29] Indeed, conspiracies – being actions organized to achieve an end sought by a group having common interests – have much in common with professional activities; by attempting to control the former, one is likely to stifle the latter.[30]

### *Geographical segregation: national protection and regional isolation*

Three factors are notable for the postwar decade. First, as noted above, security concerns and protective legislation isolated the three former allies. The three countries reduced their collaboration in atomic energy substantially, and their laboratories mimicked this traditional response to external threats.[31] Second, national programs, and their goals, expanded rapidly. Third, this activity was concentrated into a handful of postwar research centers under the scrutiny of their central governments.

Paul Forman has highlighted the unusual compartmentalization of postwar national labs, with rapidly growing expertise ring-fenced against the threat of espionage.[32] Site segregation was important for breeding the first cohorts of nuclear specialists. In the three countries, about a dozen government-sponsored facilities specialized in distinct aspects of nuclear technology, providing what radiochemist Glenn Seaborg later characterized as 'small islands of technical information sealed off from society.'[33] Almost as a by-product of those activities, a cadre of atomic energy specialists was gestated and nurtured. In these cloisters, nuclear workers were formed in peculiar postwar environments with ample resources, cosseted in secure workplaces and isolated from contaminants. Like novice monks in religious orders, this period of incubation shaped their development and mature identity.

The wartime installations were expanded into national laboratories which were to focus resources on distinct intellectual terrain. The Canadian center at Chalk River made the transition to peace-time with few immediate changes, but the new US Atomic Energy Commission (AEC) decided that Argonne would continue as the US center of reactor technology, with Oak Ridge relegated to separation processes and chemical technologies – a categorization resisted by Oak Ridge technical staff, who continued to pursue reactor engineering by interpreting these categories liberally.[34] New postwar national laboratories included the Brookhaven National Laboratory in the USA, which engaged in some reactor development work, the Atomic Energy Research Establishment (AERE, Harwell, 1946) – the British equivalent of Argonne and Chalk River – and the Atomic Weapons Research Establishment (AWRE, Aldermaston, 1950), the British equivalent of the Los Alamos and later Lawrence Livermore Laboratories in the USA.[35] The Industrial Group (1947) of Britain's new Department of Atomic Energy, headed by former ICI engineer Christopher Hinton, assumed responsibility for the engineering of piles and separation processes, and had no exact US equivalent.[36] In both countries, production sites – Hanford and later Savannah River, South Carolina, in the USA, and Windscale, Cumbria, in the UK – mixed engineering and science to produce plutonium via large-scale reactors.

Owing to shortage of skilled specialists, the major industrial contractors agreed to restrict the regional transfer of expertise. Not only did employees have to submit to an unprecedented degree of site security, but they were literally cloistered by their job conditions: Hanford production workers could not apply to Du Pont for new Savannah River posts without seeking permission from their current employer, General Electric. The administrators of the national laboratories negotiated similar agreements to prevent the poaching of their senior engineering and scientific staff.[37]

Interpretations of the McMahon Act also discouraged Americans from joining foreign establishments. An academic at the University of Chicago, for example, hesitated to accept an engineering post at McMaster University in Ontario because a colleague advised that he could be convicted of divulging US atomic secrets to his students. While dismissing such fears, university and Chalk River administrators could offer only diffident assurances that

> there is not the slightest chance of ... being prosecuted for carrying on ordinary teaching and research work at any university, providing always that he observes what he is morally and ethically bound to do; that is, not to pass on directly, and as such, specific technological

information which he has obtained as a member of one of the super-secret projects in America.[38]

Having failed to attract Walter Zinn, the Canadian reactor expert and wartime associate of Enrico Fermi, to lead the Chalk River program, the Director fumed that security further stifled recruitment: 'there are a few on the staff here who are working on subjects which they are free to publish and are very likely to leave if publication were not possible.'[39] The Canadian program, having lost its British contingent and indirectly subject to the US security regime, thus found itself starved of expert labour in the early postwar years.[40]

Physical separation abetted such isolation. The heart of the new field was the reactor, and all were situated at geographically remote or isolated sites far from population centers to obviate the risk of explosion or radioactive release – in the hills of Oak Ridge, Tennessee; at Hanford, Washington, surrounded by the northern desert of the Pacific Northwest; in the forests at Chalk River, on an isolated stretch of the Ontario/Quebec border.[41] At several of the sites, segregation extended from the workplace to private life. Chalk River's associated town of Deep River, located 18 km away, had controlled access via security gates, barriers and guards to restrict access by casual visitors and the curious press – a 'company town' having equivalents at Hanford and Los Alamos. While not segregated by sex, such sparse environments had many of the trappings of a monk-like existence and encouraged participants' strong commitment to their projects.[42] Similar operational security was a feature of the new occupations at the British atomic energy establishments, situated on former military bases. A reporter touring the still-incomplete Harwell establishment in 1948 noted that 'our first sight of Harwell [was of] the ten-foot high barbed wire fence around the establishment. The first people we met were uniformed War Department Police and plain-clothed security officials of the Ministry of Supply.'[43]

At the US national laboratories, security concerns during the first postwar years were relatively uncontentious; the creation of the nominally civilian US Atomic Energy Commission (AEC) meant that the military organization imposed by the Manhattan Project was somewhat relaxed. On the other hand, the now publicly known atomic energy facilities raised new security concerns about espionage, and worked against openness. Walter Zinn, Director of Argonne National Laboratory (ANL) and of the US reactor development program, casually excused its 'startlingly large number' of security personnel as 'required due to the multiplicity of locations and due to the insistence of the Atomic Energy Commission that all areas be under guard.'[44]

### *Cosseting*

These secure environments also had some advantages. They were safe places for those who gained entry. Even during the late stages of the Second World War, the Met Laboratory personnel had had the luxury of speculating about future applications. This was a unique working environment for the participants: as Alvin Weinberg, long-time Director of Oak Ridge National Laboratory (ORNL) recalled, 'Everyone could play the game of designing new nuclear power piles . . . . Crazy ideas and not-so-crazy ideas bubbled up; as much as anything because the whole territory was unexplored – we were like children in a toy factory.'[45] The wartime Anglo-Canadian project offered similar freedom to muse. The Canadian pile became operational in September 1945, four weeks after the Hiroshima uranium and Nagasaki plutonium bombs were dropped.[46] For the Anglo-Canadian group focused on reactor theory and building the first Canadian reactor, the use of the bombs themselves was marked by relatively little reaction. Cockcroft had spent the weeks preceding the Japanese events writing a scientific account of chain reacting systems, and the month before that was devoted to a memo outlining postwar possibilities for generating power.[47] While bomb design had urgency, the development of reactors encouraged expansive dreams.

The postwar environments of the national laboratories further liberated their specialists to explore the possibilities of atomic energy for transmuting elements, applying them to medicine and agriculture, generating power and any number of other possibilities. Funding was copious, especially in the USA. Research could be undertaken with relatively beneficent financial scrutiny. For the Canadians in particular, the new 'Atomic Energy Project' had an open remit of exploration.

### *Intellectual isolation*

The physical isolation of secure sites bred intellectual isolation, too. As Peter Galison has discussed, the classification of knowledge – military secrets, trade secrets, inventive expertise – accelerated during the twentieth century and especially after the Atomic Energy Act of 1946 ('the founding document of modern secrecy') with profound consequences.[48] Governments had been careful to contain the circulation of nuclear knowledge that could have military, commercial or other advantage. Expertise having potential for threatening national security was particularly suspect, and most nuclear knowledge could be, and was, interpreted in this way. Thus, a Committee on Declassification set up by General Groves in 1945 had generally opted to withhold both 'facts of nature' and engineering data.[49] The ostensibly civilian AEC interpreted 'restricted data' just as conservatively to include not just 'all data concerning the manufacture or utilization of atomic weapons,' but also 'the production of fissionable material [and its use] in the production of power' or other applications.[50]

It was similar in the UK.[51] The McMahon Act provided an operational model for British practices, imposing a layer of secrecy over the national program. Although the mutual American–British concealment was motivated by economic as much as military confidentiality, the perceived threat of Soviet espionage dominated the following decade. Indeed, the Division of Atomic Energy was sometimes more cautious than its US counterpart. In reviewing a proposal by the AEC Director of Classification, Christopher Hinton admitted that the current secrecy was 'unhealthy and undesirable,' but argued that more than 'the technology of advanced reactors and the design of atomic weapons' should be classified; the British view was that 'instrumentation, health physics and control techniques in connection with reactors' also should not be considered open fields.[52]

As Galison argues, nuclear security, while having few guiding principles, bore a strong resemblance to long established trade secrecy. Manhattan Project administrators had feared British commercial interests in atomic energy, and postwar British access to American information was even more seriously curtailed. The same was true within the UK: despite the embedding of ICI's working culture in the new atomic factories, Hinton found technical information about even mundane factory equipment difficult to obtain from his former employers owing to old-fashioned commercial confidentiality.[53]

Despite the non-military orientation of the Canadian atomic energy project, Chalk River administrators mirrored American clearance procedures in part to encourage reopening collaboration but, in the short term, merely to allow Canadians to receive

American classified training. Some courses – particularly those at the Oak Ridge Institute of Nuclear Studies (ORINS, 1947) on the use of isotopes (the least secret of the secret technologies) – considered and occasionally granted access to vetted Canadian and British workers. Even so, requests by Canadian scientists to attend ORINS had to be channeled from Chalk River consecutively to the Canadian Department of External Affairs, the Canadian Ambassador in Washington, the US State Department and the FBI, because US officials mistrusted Canadian security procedures.[54] Yet this was still a limited concession. That mistrust meant that courses at the neighbouring Oak Ridge School of Reactor Technology (ORSORT, 1950) remained firmly out of bounds.

In terms of intellectual isolation, then, the USA, UK and Canada followed broadly similar paths.

## *Filtering*

While the classification of information shaped activities at the national laboratories and beyond, for individual engineers and scientists working on the national atomic energy programs there was a more personal relevance of security: its influence on employment and career progression. Given the security context, it is not surprising that the political backgrounds of potential staff in each country were vetted. It is equally clear that this scrutiny was seminal for the first cohort of specialists. They worked for a single employer: their government. It meant that a politically filtered generation was admitted to the new field.

Loyalty oaths for new employees, for example, were replaced by mandatory FBI checks at Argonne in 1950, which could also be instigated by anonymous reports or suspicions after employment.[55] These expressions of symbolic secrecy had more individualistic outcomes, however. AEC workers suspended under the Atomic Energy Act after an FBI investigation could find themselves denied due process by the Personnel Security Review Board, unable to learn the charges against them or to cross-examine witnesses, because the Commission was unwilling to reveal its sources of information.[56] While specialists denied posts at the national laboratories often found employment at firms or universities engaging in non-classified work, the risk of career consequences was considerable: government-sponsored research was growing rapidly at industrial research establishments and universities, and it appeared that political liberalism was being identified increasingly as disloyalty.[57] Ritualistic avowals of loyalty, like the recitations of matins prayers in monasteries, thus carried inordinate weight in working life.

This scrutiny of political views was more contested in the UK and Canada, which had not embraced the same degree of communist suspicion as in the USA. The personal dimension of security was well characterized by British physicist Neville Mott: 'Anyone entering a government establishment will know that for the rest of his career his political life and associations will be under observation, and his advancement and perhaps his job will depend on them. This will not add to the attraction of a career in government service.'[58] As emphasized above, this environment affected engineers and lower-tier technical workers even more assuredly than relatively vocal scientists. Postwar organizations of nuclear workers – including substantial numbers of engineers as well as scientists – addressed the national, professional and personal consequences of government security policies.[59]

### *Categorization and representation*

The filtering of employees could also operate more subtly through the management of union representation. Because Du Pont had never unionized its commercial plants, most of the wartime and postwar reactor operations personnel were not union members. The segregation of the Manhattan Project and later national laboratory sites, as well as the unfamiliar job categories attached to the new atomic processes, had inhibited union representation further. What was true for the technical and engineering staff was equally true for the scientists: the universities, acting as contractors for several Manhattan Project sites, were mostly non-union employers: the University of Chicago, for example, had no union agreement extending to Met Laboratory or Oak Ridge personnel.

From the government viewpoint, organized labour could effectively map the workforce to national objectives, but equally could oppose and disrupt those objectives for the more self-interested goals of its members. Wartime American unions accepted the argument that, unlike construction workers, the process workers at Du Pont's Hanford piles and plutonium separation plants were privy to classified information, skills and equipment to carry out their jobs, and that the processes they controlled were particularly vulnerable to disruption or damage if, for example, work stoppages or strike action were taken. Nevertheless, local branches contested Manhattan Project management of numerous aspects of labor relations.[60]

After the war, when US labor unions reached their largest expansion, there was more maneuvering room for organization of skilled workers at the production facilities. For site administrators, though, unionization represented a loss of control. It threatened to provide a back door for divisive voices, and even for external subversion. At best, the bargaining tool of strikes or other withdrawal of labor would be unpatriotic, limiting production of nuclear materials deemed essential for national defence; at worst, they could inhibit removal of suspect employees and so facilitate espionage.[61] More than any other profession in the postwar period, then, nuclear workers were sequestered and categorized by their governments. Union representation – particularly on the national scale – challenged not just working conditions, project goals and operating costs, but the emerging public message of atomic energy.

For such reasons, unionization of postwar AEC technical staff was initially resisted by administrators. Having interviewed employees in 1946, agents of the Intelligence Office at the Hanford Engineer Works suggested, for example, that there were no grievances requiring collective action, reporting that the 'benevolent paternalism' prevailing at the site was 'strikingly illustrated by the often repeated query, "What does the government and General Electric wish us to do?".'[62] Yet there was a quandary: the restriction of information demanded by site secrecy could, they implied, encourage unpatriotic self-interest and a dangerous element of organizational instability:

> most of the membership [of one of the new unions] do not understand the importance of the Hanford Engineer Works and ... are not aware that about a year ago for security reasons President Truman asked unions not to organize, nor that in April, 1946, the Secretary of War requested ... they not organize at Hanford.[63]

Other sites evinced the same concerns. At the Argonne National Laboratory, the Board of Governors discussed 'the union problem,' and forecast that the existing unions might create 'some trouble' when the Atomic Energy Commission Review Panel began dealing with the 'security cases' in 1948.[64] Not until the Eisenhower administration's revised Atomic Energy Act (discussed below) did unionization spread, and mainly to lower-tier workers: in 1954 General Electric signed a contract with an assortment of craft unions, the Hanford Atomic Metals Trades Council and, the following year, US nuclear workers represented principally by the Chemical Workers' Union combined with those in the oil and chemical industries to form the Oil, Chemical and Atomic Workers' Union (OCAW).[65]

British labor policy during the same period had a different emphasis. The secrecy of specialist atomic knowledge was an undercurrent that influenced professional identity of engineers and labor representation of skilled nuclear workers even more overtly than in the USA, and focused on the potential danger of unions as harbors of destabilizing political subversion. The UK Atomic Energy Authority (UKAEA), as the employer and educator of most British nuclear workers in the mid 1950s, sought to shape its workforce and public attitudes concerning them.

Canadian representation of nuclear workers was distinctly different owing, in part, to the eschewing of military applications of atomic energy. Just as the UKAEA had inherited ICI disciplinary divisions and Ministry of Supply practices regarding trade unions, Chalk River shaped its workforce according to the template of the National Research Council. Unlike the UK, the Canadian Atomic Energy Project encouraged its employees to unionize with fresh identities bearing novel and, one might presume, status-bearing categories.[66]



### *Rising security and its effects*

Towards the end of the decade further events interpreted as destabilizing to US interests seemed to vindicate the policy of rising security. In September 1949, the Soviet Union tested its first atomic bomb; a month later, with the declaration of the end of the Chinese civil war, Mao Zedong signed a mutual assistance pact with Joseph Stalin; and, in mid 1950, North Korea invaded the south. These events, overtly provocative to Western eyes, were mirrored by unsettlingly covert ones, too. Espionage was discovered repeatedly within the nuclear programs.[67] Jessica Wang has well portrayed how this age of anxiety affected US scientists, if not engineers.[68] Indeed, postwar organizations such as the AEC were top-heavy with scientists, and underrepresented engineers both publicly and privately. Yet such incidents seemingly were perpetrated by foreign scientists, vaunted by their governments as the creators of the atomic secret, and by some of their US engineering counterparts, even though security measures affected all nuclear workers.[69]

The first atomic spy scandals, involving scientists Allan Nunn May (made public in March 1946) and Klaus Fuchs (February 1950), and the defection of University of Liverpool scientist Bruno Pontecorvo to the Soviet Union (August 1950), had links directly to the origins of the three atomic energy programs. The filtering of project personnel was correspondingly increased. When Fuchs, Head of Theoretical Physics at Harwell who had worked at Columbia University for the Manhattan Project, was convicted of espionage, security measures in Britain increased further – so much so that the Atomic Scientists' Association (ASA) issued a statement hinting at Stalinesque excesses in 'the Civil Service purge of persons who are members of extremist political organisations and likely to weaken national security.' The ASA urged the British government not to extend security to other institutions such as industry and universities.[70]

This reputed connection between political viewpoint and reliability affected nuclear specialists at every level. In Britain, the ASA, representing mainly scientists and engineers, steered an awkward 13-year course between official representation and independence. Its first meeting agreed to supply technical advice for the defence in the espionage trial of Allan Nunn May, and such forthright stances appeared dangerous to some.[71]

While employees of the Division of Atomic Energy were well represented in the ASA, they complained increasingly about some of the public positions it adopted. For example, the *Atomic Scientists' News* argued that the British program was excessively cautious about security criteria, a claim strongly denied by a Council member.[72] Internal debate raged about the representation and political role of the ASA. One of its Vice Presidents argued that the Association was unrepresentative of the genuine cohort of specialists employed at the government research centers: 'therefore in most ways the real Atomic Scientists have to be represented by others – partly ex-Atomic Scientists and partly people who have never had anything to do with this type of work.'[73] John Cockcroft, although serving as a VP himself, argued that the Civil Service discouraged its employees from holding office in such an association, with the result that 'the initiative is apt to pass into the hands of the very left wing scientists.'[74] Engineers, while working alongside such activist scientists, remained a nearly invisible constituency during this period.[75]

National filtering was also increased. Senator Pat McCarran (1876–1954) subsequently sponsored two bills to limit communist influence on US research institutions (see Table 1). The Internal Security Act (1950) and Immigration and Nationality Act (1952) limited entry to the USA by foreign scientists, technologists and educators. The visa restrictions imposed by the State Department further isolated Americans from their international peers.[76] The British government was equally wary in the months after Pontecorvo's defection. When the passport of physicist E.H.S. Burhop was revoked after he had accepted an invitation to visit Moscow in 1951, a flurry of protest to the 'island arrest' led to its reinstatement, with the caution that Burhop consult the Foreign Office before considering any visit to a country in the Russian orbit.[77]

The American espionage case of Julius and Ethel Rosenberg – arrested in 1950 and executed in 1953 – further challenged the reliability of lower-tier nuclear workers, and provided ammunition for Senator Joseph McCarthy (1908–57) to prosecute a campaign alleging communist subversion throughout American institutions.[78] For a period of four years, during most of which the stalemated Korean War exacerbated paranoia, McCarthyism heightened national security through narrowly conceived patriotism.

For US nuclear workers there were three forms of fall-out: an increased demand for urgent nuclear development and production, more arduous loyalty checks and rising levels of security. Their counterparts in Britain and Canada, hoping to regain contact with their US peers, adopted similar security measures. Chalk River consolidated its status as a closed site accessible only to cleared visitors. As perceived international and domestic threats grew, its borders became more immiscible: the Canadian press was refused access, and the editor of *Nucleonics*, the first US periodical in the field, was even more summarily dismissed.[79] Indeed, John Cockcroft, Director of AERE Harwell, was irritated to discover that tighter security procedures applied equally to British, Americans and Canadians visiting Chalk River.[80] Americans, too, chafed at the heightened security. Even though a USAEC liaison officer remained based at Chalk River, at least one colleague at Hanford urged that current restrictions on exchange of information be liberalized for US benefit.[81]

This ratcheted security had operational drawbacks. During the early 1950s, secrecy became increasingly complex to manage; crosschecking how secrets could inadvertently be revealed through innocuous publications was becoming arduous. At the same time, declassification was being superseded by the rise of independent nuclear research conducted in other countries. After the Soviet Union detonated its first atomic bomb, the US committee on declassification decided that there was nothing to lose, and perhaps something to gain, by fully revealing some simple reactor designs.[82]

Security constraints also hampered industrial contributions to national objectives. Du Pont was stymied in 1950 when the US government urged the company to assume a new postwar responsibility – designing and operating a new generation of plutonium reactors at Savannah River, South Carolina, to supplement the rapidly deteriorating Hanford, managed since 1946 by General Electric. Its engineering managers – shuttling between the now established national laboratories at Argonne, Oak Ridge and Brookhaven to consult on design details of the planned reactors – discovered that the knowledge developed over the intervening five years was either classified or stored at specific restricted laboratories.[83] One senior engineering manager complained that the AEC offered no training courses for pile physicists, and that suitable instructional material was not available in coherent form.[84]



### *Restricted diffusion: security in training and dissemination*

The questions of engineering knowledge transfer and training were perennial for AEC contractors. Because of secrecy, the growing expertise of nuclear engineering could not be taught at colleges or universities.[85] Pooling resources and scarce expertise, Du Pont and General Electric agreed to support a joint training school at the Hanford site, despite the companies' different industrial cultures: for Du Pont engineers, Hanford was a versatile and malleable collection of plant for producing a chemical product; for their GE successors, the reactor was a product in its own right, akin to the industrial transformers and generators that had made the company's fortune. This disciplinary oscillation illustrates the tentative embedding of their new knowledge and its sensitivity to local context – both exacerbated by site segregation.

From the perspective of would-be nuclear specialists, such collaborations were unusually restrictive. All the early courses on the deeper aspects of atomic energy were given at government facilities, usually for selected participants from the military services, industry and universities. Research and teaching of classified nuclear topics to restricted audiences had begun on a small scale at the Oak Ridge Laboratory and MIT in 1946. Postwar policy on education was summarized by Major General Kenneth Nichols (1907–2000), former deputy to General Groves, who argued that 'secrecy and government control of the atomic energy field may appear to be limiting factors' for an educational program, but that concerns about security could be overcome by government sponsorship – via AEC contracts or through temporary employment of academics at the National Laboratories and AEC industrial contractors.[86] The new discipline would, in short, be state managed.

The best example of this sponsored training was at the Oak Ridge School of Reactor Technology (ORSORT, 1950), available until 1960 only to vetted US citizens.[87] The curriculum, further restricted to engineers and scientists sponsored by the AEC and by US industries holding AEC contracts, conformed closely to government directives, 'determined by the status of the declassification program at the time the courses are presented.'[88] British and Canadian training followed the same model at the security-conscious Harwell, Windscale and Chalk River sites until the launching of university programs in the late 1950s. Indeed, the British model continued to rely on training by the UKAEA to supplement further education.[89] Such training facilities underlined the monopolistic direction of the new disciplines of nuclear engineering by national governments, and their disconnection from conventional higher education establishments.

Like technical training, the publication of books and journals was centrally regulated and locally managed for a decade after the war in much the way that monks selected, protected and reproduced monastic knowledge. While copious articles and books popularized the aspects of atomic energy that had been revealed in the 1945 Smyth report, few went much further. The first journals carrying details on atomic energy had been 'published' for restricted audiences.[90] The first textbooks were censored to protect sensitive details: *Elementary Pile Theory*, published in 1950 from declassified notes of the Clinton Laboratory, was a mere 71 pages long. As its foreword emphasized, 'the greatest part of the work is still classified, and probably will remain so for some time.'[91]

Yet, as argued by Shils and Moynihan, controlling the flow of information disadvantaged program goals. Du Pont's subcontractors were required to implement security measures when working on and storing classified information, requiring isolated offices and locked repositories. Managers recorded being 'severely handicapped' by the lack of cleared personnel to handle classified information, and the need for technical personnel to be investigated for security risk through the remote New York Operations Office.[92] The architectural company designing the buildings for Savannah's heavy-water plant, for example, required 175 employees to be cleared to Q, the highest security level, presumably because details of spaces and installed equipment could reveal production methods and capacities. So time-consuming were these tasks that at one point the AEC had to issue Emergency Clearances for drafting personnel to complete their tasks on schedule.[93]

## Peaceful applications: raising the veil

Thus the security surrounding atomic energy, its knowledge and its specialists, waxed and waned between 1940 and the early 1950s. Proto-professions consequently were discouraged in each country, and engineering practice and collective identity gradually diverged at the half-dozen sites dedicated to reactor technology. In mid decade, however, two international events publicly realigned atomic energy development towards peaceful applications, loosening classification and bringing new occupational clarity for nuclear engineers.

President Eisenhower's December 1953 address to the United Nations on 'Atoms for Peace' sought to address the increasingly unworkable security regime for nuclear technology. The speech capped his government's efforts to publicize to Americans the loss of the monopoly on nuclear weapons and the growing momentum of the Cold War. It initially had begun as an extension of the Administration's 'Project Candor,' a public relations initiative that would stress the dangers of 'Soviet capabilities, and on the rapid growth of the Soviet economy' with a strong undertone stressing the inevitable slipping away of nuclear 'secrets,' but was recast positively as a 'revelation of atomic power.'[94]

Despite its title and vague aim to provide 'abundant energy for the power-starved areas of the world,' a briefing paper coached US spokesmen that it was not a 'plan for exchange of atomic secrets with Russia or anybody.'[95] Atoms for Peace was first and foremost a media-wise re-education of the US public; secondarily, it opened possibilities for US-led dissemination of not-so-secret atomic secrets, via, for example, the ORINS isotopes school. The US relaxation influenced Britain as well. That year, the UK reorganized its own program from the civil service Department of Atomic Energy, tasked with weapons development, by founding the UK Atomic Energy Authority, with its new role 'to design, build and operate new types of reactor.'[96]

Eisenhower's initiative also prompted international responses that dramatically shaped the nature of nuclear engineering. The UN conference on the 'Peaceful Uses of Atomic Energy' held in Geneva in the summer of 1955 brought together the countries that had been working on atomic energy in isolation for a decade. To the surprise of most participants, the specialists in each country were able to release details of their work that had been secret months earlier. The propaganda advantage of openness proved compelling, and a flood of technical information resulted.

The Geneva Conference was cathartic for nuclear specialists. As the Director of ORNL recalled, nuclear workers, along with governments and industrial contractors, were swept up in the outpouring of information:

> ... the conference was presented with a vision of a future energy-hungry world for which nuclear power was a panacea .... The tone of Geneva I was euphoria! And every one of us was caught up in this enthusiasm: our supreme technical fix, inexhaustible energy from uranium, would set the world free![97]

Soviet public expressions were similar in tone and content, employing terms such as 'limitless possibilities,' 'the power of our age' and 'miraculous progeny.'[98] Indeed, historian David Holloway ends his historical account of Soviet nuclear developments with the feting in the west of Igor Vasil'evich Kurchatov (1903–60), the scientific director of the Soviet nuclear project – shaking the hand of Walter Zinn, his US counterpart in reactor technology, at Argonne, and 'breaking the spell' of secrecy for John Cockcroft, his equivalent at Harwell – interactions made possible by the new openness.[99]

### *Public and professional identity*

Only after Geneva were nuclear engineers publicly distinguished from their scientific counterparts. The new rhetoric of atomic energy encouraged effusive praise for the designers, builders and operators of facilities having peaceful purposes and public benefits. The channels for such messages multiplied through a raft of journals, books and courses, as publishers and university departments scrambled to appropriate the newly liberated knowledge.

As a result, the mid-decade thaw permitted a growing sense of common purpose and professional identity among nuclear experts. In the USA and UK, societies of nuclear specialists were founded. The American Nuclear Society, appearing in the months after Atoms for Peace, was dominated by those employed in the national laboratories – particularly Argonne and Oak Ridge – and by employees of AEC industrial contractors. Its earliest activities were to organize open conferences and to launch a new journal, *Nuclear Science and Engineering*, that were not restricted by controlled circulation.

As this suggests, new publications represented a pent-up pressure for greater publishing freedom and collective identity. In the UK, publisher Robert Maxwell's Pergamon Press created a series of nuclear engineering journals beginning with *The Journal of Nuclear Energy* (1954) and *Nuclear Engineering* (1956); and, illustrating the eagerness to gain ground, another UK magazine publisher transformed *Combustion and Boiler House Engineering* into *Nuclear Energy Engineer*, the vehicle for his new Institution of Nuclear Engineers (INucE, 1959), the first organization to seek professional credentials in the field.[100] Unlike the ANS, however, the INucE was founded from a more disparate group aligned with the emerging nuclear power industry. They were resisted by senior figures in the Atomic Energy Authority, particularly by Christopher Hinton, who urged that conventional engineering disciplines could accommodate what he characterized as the narrow specialists of atomic energy. The features of this episode, involving jockeying for intellectual space, jurisdiction, status and identity between occupational groups in a shifting ecology of professions, is well described by the sociological model of Andrew Abbott.[101]

The new periodicals gave a voice to both established and novice participants in atomic energy, all favouring the lowering of security for common benefit. This circulation of knowledge after a decade of secrecy, argued John Cockcroft, was crucial to the subject. Introducing the first issue of *The Journal of Nuclear Energy* in mid 1954, he lauded the progress possible by the 'interchange of ideas which is the basis of scientific and technological development in peace.'[102] American counterparts emphasized a similar point. An editorial in *Nucleonics* magazine even offered to expedite the supply of the little information yet available, 'to assist any reader, especially those in foreign countries, in getting non-secret information in the atomic energy field . . . by advising on availability and sources of information.'[103]

British magazine editorialists, allied with the emerging nuclear power industries rather than the UKAEA, vaunted the optimistic commercial future made possible by rejecting secrecy, and predicted the internationalization of nuclear engineering. The first issue of *Nuclear Engineering*, for example, identified national differences in the subject as a direct and undesirable consequence of security, and an aspect that would soon fall to an internationalization of the subject:

> . . . at Geneva last August . . . it became obvious that . . . the divergences that had occurred were forced by local conditions rather than by fundamental conceptions. Similar conditions will prevail in a single country unless an adequate exchange of views and information is encouraged.[104]

John Cockcroft more pointedly praised the new atmosphere at Harwell:

> [Before Geneva] the courses held at the school were secret and only British subjects could attend them . . . . At this Conference, a very large amount of information on reactor technology was publicly released for the first time; indeed, the amount of 'declassification' which took place at Geneva was so great that it became possible to hold completely unclassified courses at the Harwell school, and meant, of course, that foreign students could attend.[105]

And Cockcroft's industrial complement, Christopher Hinton, emphasized the commercial and occupational benefits in the inaugural issue of the *Journal of the British Nuclear Energy Conference*, noting that while the British industry 'had worked behind a curtain of secrecy . . . nuclear engineering had now emerged from that stage . . . as an important industry in its own right,' and civilian electrical power would give more freedom and opportunities for employment to its workers.[106]

## Enduring consequences

It is tempting for participants and historians alike to frame nuclear accounts as a story of repressive and paranoiac concealment superseded by enlightened candidness, but a more nuanced account reveals otherwise: the heritage of security proved enduring for the careers of nuclear specialists.

Despite mid-decade exhilaration, the smoke of classification was slow to dissipate. In the wake of the Geneva Conference, *The Bulletin of Atomic Scientists* dedicated an issue to the ongoing problems of secrecy.[107] And only 18 months after the conference did a new tripartite declassification guide issued in Washington, London and Ottawa promise to allow free mutual access to all phases of civilian nuclear power, but leaving other domains still unrevealed. As a result, 'the last remaining vestiges of secrecy' at Britain's Calder Hall were to go, and information would be 'freely available on fuel element fabrication and reprocessing.'[108] While national security was being toned down, however, commercial secrecy remained a concern: Britain, the USA and Canada maintained strong hopes of eventually exporting their technologies. Reactor economics and waste disposal were also to remain sensitive areas that encouraged a defensive posture and considerable reticence for the industry and its participants from the time of the first Geneva Conference.

Ironically, the Windscale accident of October 1957, during which one of the two British production piles caught fire and released radioactivity regionally, was an opportunity for an unusual degree of information sharing between British specialists and their long-estranged American colleagues. General Electric engineers noted that 'some very nice fundamental work,' with 'very capable technical people working on graphite problems at Windscale and an equal number at Harwell . . . . This information would be helpful in extrapolating present experience to future Hanford operations.'[109] Openness remained episodic and incomplete between the two countries through the following years.

The British government mistrust of nuclear workers also persisted after Geneva. In 1957, the Secretary of State, Selwyn Lloyd, tarred an ASA report on the medical effects of nuclear fallout as a product of 'people with strong fellow-travelling tendencies and leanings.' In providing guidance for a government apology, a civil servant noted privately, 'The Atomic Scientists' Association, as is normal with associations of scientists, has its share of political innocents (and at least one known Communist sympathizer): but as a whole ... are reputable, if somewhat naïve, bodies.'[110] By 1959, the continuing pressures dividing social conscience from occupational allegiance to the UKAEA proved too much for the ASA officials: the organization disbanded, with most of its activities transferred to the British Association for the Advancement of Science, and published via the magazine *New Scientist*.[111]

While the relatively elite atomic scientists were cowed by such clashes, nuclear engineers and technicians were even more effectively controlled. Security concerns continued to isolate British nuclear workers as an occupation and filtered their ranks as a skilled workforce. Thus when Labour MP William Griffiths complained in 1960 that UKAEA job advertisements did not mention security clearance, despite 'the past record of the security services in dealing with persons of "left-wing views,"' the Minister of Science replied, much as he would have done a decade earlier, that 'the chief risk is ... that the Communist faith overrides a man's normal loyalties to his country and induces the belief that it is justifiable to hand over secret information to the Communist party or a Communist foreign power.'[112]

On a level less visible to the public, labour representation specific to this still-isolated domain continued to be discouraged. Categorization, shaped by security concerns, restricted the emergence of new occupational labels for those employed in atomic energy. For example, The National Union of Atomic Workers (NUAW), founded at Capenhurst, Cheshire in 1958 to represent craft workers, launched branches with over 2000 members at five UKAEA facilities within a year. It challenged the existing (and Authority recognized) unions, the National Union of Municipal and General Workers and the Transport and General Workers Union, as anachronistic and poorly representative of the special skills and unique working environment of its members. The Authority was steadfast in refusing to recognize the upstart group however and, denied bargaining power, membership rapidly waned, disappearing by 1963.[113]

Fifteen years later, security anxieties had faded substantially but the role of unions in consolidating professional identity was no clearer for more senior specialists. The Institution of Nuclear Engineers noted that no British unions proffered identity along the lines of disciplinary specialty, nor acknowledged the special occupational conditions of work with radioactivity. Indeed, because of the ongoing competition with the UKAEA-supported British Nuclear Energy Society, the Institution itself achieved only junior membership among the engineering professions, offering little professional visibility for its members.[114]

The field continued to be hamstrung by secrecy through the 1960s and beyond, with the quantity of classified information continuing to expand exponentially in the USA.[115] The UKAEA, USAEC and AECL each encouraged reticence about the economics and safety of their nascent industries, a heritage of security that arguably has endured. And concerning domestic threats, the Nixon administration (1968–74) had strained relations with both the Oil, Chemical and Atomic Workers' Union and vocal employees of the Argonne National Laboratory.[116]

As this suggests, the public representation of nuclear specialists continued to be mediated largely by their governments and employers. Security had shaped working environments and professional relationships enduringly. In the USA, the primary source of professional identity had been the Argonne National Laboratory and its first Director, Walter Zinn, both emerging from the wartime Met Laboratory. In the UK, a distinct identity for nuclear specialists had been shaped at Harwell and within the Industrial Division of the UKAEA by their first directors, John Cockcroft and Christopher Hinton. Hinton had shaped the British nuclear cadre by defining them as variants of existing technical professions, and playing a seminal role in tailoring UKAEA and subsequent university training programs accordingly. In Canada, occupational identity was inherited from the pre-war blend of engineering and scientific labour existing at the National Research Council, having much the flavour of a national standards laboratory. These organizations – and the companies that grew to support their development programs and national industries – continued to serve as the public proxy of nuclear specialists. As a cadre of experts born out of shrouded government projects and later employed by restricted industries, nuclear workers largely accepted their relatively voiceless role.[117]



## Conclusions

I have argued that three phases of security surrounding national atomic energy projects shaped the field of nuclear engineering and its specialists profoundly, but with relatively subtle differences between the three wartime allies. The Manhattan Project, the postwar period between the 1946 McMahon Act and the 1955 Geneva Conference, and the subsequent beginnings of the commercialization of nuclear power, identified distinct threats from the circulation of knowledge and personnel. National governments consequently played a unique role in defining the nature of the subject by filtering the workforce, subsidizing and segregating development, defining occupational identity, helping to create disciplinary categories, and in supporting particular forms of professional identity. As 'a form of government regulation,' to quote the Commission chaired by Daniel Moynihan, secrecy thoroughly shaped these specialists.[118]

Security of information encouraged locally defined and isolated disciplinary foundations and fostered a monastic mind-set. The Manhattan Project had promoted compartmentalization and increasing divergence of intellectual foundations and technique. At the same time, the urgent activities of large technical teams gave them rapidly accumulating experience unique to each site. The result was not just regionally distinct programs, but dissimilar nuclear specialists, too.[119]

National distinctions centered on the categorization of these specialists. While *nuclear engineer* became a viable label at American research and production sites directed by the US Atomic Energy Commission and administered by firms such as Du Pont and General Electric, and consolidated by their support of the fledgling American Nuclear Society, the term was contested in the UK. Seeded by ex-ICI personnel, the UK Atomic Energy Authority promoted the integration of atomic energy expertise as a branch of process engineering. Its senior administrators shaped occupational identity by allocating lower-tier nuclear process workers to existing job categories and encouraging their affiliation with pre-existing unions. Higher-tier professional aspirations were stifled by the resistance of British professions and UKAEA to the upstart Institution of Nuclear Engineers. Canada's program was equally influenced by institutional cultures: growing from the National Research Council environment of close cooperation between engineers and scientists, specialists had relative freedom to explore reactor technologies and, for the lower-ranked engineers and skilled workers, at least, to vaunt their expertise through the creation of new labour unions.

These distinct national experiences, like divergent religious orders, owed much to their early segregation for reasons of security, allowing the original complement of staff and organizational culture to define an independent course sustained by the technological momentum of their reactor technologies of choice.[120] Yet secrecy imposed similarities of organization and identity, too, despite the dissimilar technological aims of the national programs. Canadian nuclear specialists at Chalk River were arguably best placed at the end of the war to continue their non-military reactor program, while their British counterparts struggled to build an organization devoted to plutonium production reactors, separation facilities and bomb design. Both countries adopted many of the features of American postwar security at their sites to encourage a more liberal exchange of knowledge after the McMahon Act. Owing to shared concerns about domestic and foreign espionage, the severity of security procedures paralleled American changes – an outcome somewhat at odds with Edward Shils's depiction of distinct patterns of 'luxuriating publicity' jostling with public 'hyperpatriotism' in the USA, as opposed to traditions of deference and privacy in the UK.[121] In each country, the political allegiances of nuclear specialists were scrutinized, selecting a cohort that met official guidelines but remained potentially suspect. In the process, participants were rendered more homogeneous on a regional scale and professionally invisible. In each national context, the state monopoly on atomic energy instilled an unusual degree of common interest with its experts and industrial contractors. In mutually supporting corporatist arrangements, all three parties promoted the national growth of nuclear power industry and a sustainable cohort of trained specialists to develop and staff it. Governments played a continuing role in representing the three parties.

As closer examination reveals, this trajectory for nuclear specialists served national interests more than the aims of professional identity. Even after program security began to relax a decade after the Manhattan Project, nuclear specialists showed lasting effects of their cloistered development. Security framed the early maturation of the field and is integral to understanding its later development. The demands of security and state management limited and filtered information in ways that arguably fostered public mistrust of atomic energy and its shadowy specialists. This history suggests enduring characteristics not just for the jobs performed by nuclear workers, but for their working identities and their capacity to engage effectively with a wider public.

## Acknowledgements

I acknowledge gratefully the funding of this work by Economic and Social Research Council grant RES-000-22-2171, and the helpful comments of colleagues, three anonymous referees and the editor.



## Notes

1. For an overview, see Hughes, 'Deconstructing the Bomb.'
2. E.g. Strickland, *Scientists in Politics*; Smith, *A Peril and a Hope*; Jungk, *Brighter Than A Thousand Suns*. On contemporary weapons designers, see e.g. Parfit, *The Boys Behind the Bombs* and Rosenthal, *At the Heart of the Bomb*.
3. French and Spanish nuclear engineers have been studied as occupational groups in young disciplines in Hecht, *The Radiance of France* and Barca Salom, 'Els Inicis de L'Enginyeria Nuclear a Barcelona.' On American craft and skilled trades workers, see Olwell, *At Work in the Atomic City*. On Canadian nuclear workers and safety in the context of radiation, see Parr, 'A Working Knowledge of the Insensible?'
4. The term *nucleonics* – an early example of specialist vocabulary demarcating the new subject – was coined at the University of Chicago's Metallurgical Laboratory in 1944. *Nuclear engineering* as a collective label found increasing use in the USA and Canada from about 1950, but remained uncommon as a descriptor and job category in the UK. On the social construction of the 'nuclear' see Hecht, 'The Power of Nuclear Things.'
5. In the USA, some 400 nuclear professionals – about half of them engineers – were estimated in 1952 and predicted to rise to 2800 by 1958 (Atomic Industrial Forum, *A Growth Survey of the Atomic Industry*). In the UK Atomic Energy Authority, so-called 'Qualified Scientists and Engineers' (QSEs) represented about 12% of the workforce and rose from 2300 to 6300 between 1956 and 1962; during that period, QSEs classified as scientists fell from 2/3 to 1/2 ('1956–1962 Programmes: Professional Manpower in the Atomic Energy Industry'). Membership in the Institution of Nuclear Engineers rose from 500 to 1100 between 1959 and 1961. By 2010, the ANS and the successor to the INucE, the Nuclear Institute, had some 11,000 and 2800 members, respectively; the Canadian Nuclear Society (founded in 1979 as a learned society rather than a professional qualifying body) has some 1200 members.
6. Shils, *The Torment of Secrecy*, especially 3.IV, and Moynihan, *Secrecy*, especially chaps 5–7.
7. E.g. Krige, 'Atoms for Peace'; Kevles, 'Cold War and Hot Physics'; Galison and Bernstein, 'Physics between War and Peace.' On the framing of secrecy for policy purposes, see Herken, '"A Most Deadly Illusion."'
8. Gusterson, *Nuclear Rites*, chap. 4; Masco, 'Lie Detectors.'
9. On analyses of distinctions between engineers on the national scale, see a thematic issue and opening essay of Chatzis, 'Introduction: The National,' and Brown, 'Design Plans.'
10. 'History of TNX,' 55.
11. Ibid.
12. The planned production pile would generate some 100,000 curies of radioactivity, the equivalent of 100 kilograms of radium and far in excess of the world's current supply. Crawford Greenewalt, the Du Pont project leader, noted that 'because of the complete lack of engineering data and because no pilot plant experiments had been made up to this time, the du Pont Company would, in ordinary circumstances, not touch a project of this nature. The grave physiological hazards involved were emphasized and it was stated that, except for patriotic reasons, the du Pont Company was opposed to having any connection with the attempt to construct and operate [such] plants' (Greenewalt, 'Stine's Memorandum'; Greenewalt, 'Manhattan Project Diary Vol I,' 88–91).
13. 'History of Operations – Administrative,' 3.
14. 832 vs. 662 workers. 'History of Operations – Administrative,' 5.
15. Hales, *Atomic Spaces*, 118; on other aspects of security, see chap. 5.
16. Newell to Thomson, letter.

17. Founded in 1916, Canada's NRC engaged in nationally relevant research with a strong complement of engineers and scientists without fixed hierarchy. In the Tube Alloy project as a whole, ICI staff made up more than a third of the total (Eggleston, *National Research in Canada*; Reader, *Imperial Chemical Industries*, 287–96; Reader, *Imperial Chemical Industries*).See also Doern, *Science and Politics in Canada* and Gingras, 'The Institutionalization.'
18. Wallace, 'Atomic Energy in Canada,' 127. The physicists' monk-like existence contrasts with the rise of team technoscience common to other parts of the Manhattan Project and described more broadly in Shapin, *The Scientific Life*.
19. Wallace to Williams, letter.
20. Mackenzie, 18 January 1943 diary. By October 1944, the Anglo-Canadian project included some 140 graduate scientists and engineers, half being Canadian, with 22 British, seven New Zealanders and four French (Cockcroft, 'Montreal Staff'). In the USA, foreign nuclear workers were quick to adopt American citizenship, particularly in light of suspicions of their allegiances; Eugene Wigner (1937), Edward Teller (1941), Leo Szilárd (1943) and Enrico Fermi (1944) were prominent examples.
21. Williams, 'The Development of Nuclear.'
22. Anonymous to Mackenzie, memo.
23. Guéron to Mackenzie, memo. See also Hecht, *The Radiance of France*. The French program was to remain isolated from work in the USA, Canada and Britain after the war, largely because of the pro-communist allegiances of key participants such as Frédéric Joliot.
24. Kowarski, 'Atomic Energy Developments in France.' Zoé, the first French reactor, was built at Fort de Châtillon, near Paris, in 1947. Brookhaven, created in 1946, was the first postwar American national laboratory.
25. 'Statement on US Censorship Policy.'
26. A 'Special Secret Committee,' established in February 1945, allowed 'US Military Intelligence and the like to have direct information on what was being done in Canada .... In addition, secret reports on the work done in Canadian laboratories on the development and improvements in analytical techniques and so on have been circulated' (Thomson to Mackenzie, letter). Seven years later, Mackenzie complained to Canadian Minister C.D. Howe that the information flow still remained imbalanced: 'in spite of a strong case and an active campaign for cooperation on the part of the American group on reactor design, up to the present time we have had no concessions whatsoever' (Mackenzie to Howe, letter).
27. Smyth, *Atomic Energy for Military Purposes*.
28. See, for example, Galison and Hevly, *Big Science*; Seidel, 'A Home for Big Science'; Weinberg, *Reflections on Big Science*.
29. Shils *The Torment of Secrecy*, 27–33.
30. As Shils notes, 'Since secrecy is so damaging to solidarity, the mere possession of a secret gives rise to the suspicion of disloyalty' (*The Torment of Secrecy*, 35); 'Within professions and professional societies, within occupational groups ... the emergence of an alleged national crisis attenuates autonomy and enfeebles the will to autonomy' (*The Torment of Secrecy*, 45).
31. On isolationism, see Shils, *The Torment of Secrecy*, 86–9.
32. Forman, 'Behind Quantum Electronics.'
33. DOE, 'Remarks by Seaborg,' 6.
34. In particular, by researching the 'homogeneous reactor,' a slurry of concentrated uranium circulated in heavy water or molten salts, summarized by Alvin Weinberg as 'a pot, a pump and a pipe' (Weinberg, *The First Nuclear Era*, 116).
35. Needell, 'Nuclear Reactors.'
36. Argonne had been unsuccessful in monopolizing reactor design owing to the resistance of Oak Ridge, but it segregated engineering to a separate site in Arco, Idaho from 1949 (later known as the National Reactor Test Station, and later still as the Idaho National Engineering Laboratory) (Stacy, 'Proving the Principle'). As Argonne Director Walter Zinn put it, 'the testing station will be a place to build reactors and get experience in their operation, rather than to do experiments such as will be done on the research reactor at Argonne by the physicists, chemists and biologists ('Minutes of Board of Governors' Meeting, ANL').
37. Church to Macki, letter; Westwick, *The National Labs*, 63; Johnston, 'Making the Invisible Engineer Visible.'
38. Mackenzie to Thode, letter.

39. Lewis to Keys, letter.
40. Bothwell, *Nucleus*.
41. As the first Chalk River reactor would be 10 times more powerful than the American pilot-plant at Oak Ridge, it was argued that the site should be no closer than 6 km from the township (Bolton to Mackenzie, letter). Similarly, the Windscale production reactors (1950) and Dounreay fast reactor (1959) were sited in sparsely populated Cumbria and the northern tip of Scotland, respectively, owing to engineering estimates of the likelihood of accident ('Choice of Site for Production Pile 1946'; Hinton, 'The Birth of the Breeder').
42. Kinsey, 'Life at Chalk River'; Behrens, 'Life at Harwell.' Unmarried employees of Hanford, Los Alamos and Chalk River were sequestered in single-sex dormitories, however.
43. Dick, 'The Hangars Hide Uranium Piles,' 281, 285.
44. Zinn to Harrell, letter.
45. Weinberg, *The First Nuclear Era*, 38–9.
46. For a detailed account of the American Manhattan project, see Rhodes, *The Making of the Atomic Bomb*.
47. Cockcroft, 'The Development'; Bauer and Diamond, 'Note on Piles.'
48. Galison, 'Removing Knowledge'; on classification of nuclear knowledge, see 232–5.
49. Beckerley, 'Declassification of Low-Power Reactors'; Manley, 'Secret Science.'
50. Argonne National Laboratory, 'Subcontractor Contract Template.'
51. See, for example, Gowing, *Reflections on Atomic Energy History*.
52. 'Secrecy in Nuclear Engineering.'
53. IME Hinton papers, 162.
54. 'Visits to Scientific Establishments – Oak Ridge Institute.'
55. 'Draft Operating Policy of the Argonne National Laboratory'; 'The New Government Employee Security Program.'
56. 'Security Procedures in the USA'; Hewlett and Holl, *Atomic Shield*, 88–95.
57. 'American Scientists Involved in Security Investigations.'
58. Mott, 'The Scientist and Dangerous Thoughts.'
59. Oak Ridge and Argonne contributed significantly to these postwar organizations. The Association of Oak Ridge Engineers and Scientists, and the Federation of Atomic Scientists, amalgamated earlier groupings of engineers, technicians and scientists. See Smith, *A Peril and a Hope*, especially chap. 3. In the UK, the Atomic Scientists' Association (ASA) also represented the technical, social and policy views of engineers in the British program.
60. 'Hanford Story, chap. 12–14.' See also Hales, *Atomic Spaces*, 169–82; Sanger and Mull, *Hanford and the Bomb* and Olwell, *At Work in the Atomic City*, esp. chaps 3, 7, and 8.
61. Concerns about unionization were often embedded in the larger-scale governmental mistrust surrounding disarmament and espionage, and was affiliated particularly with conservative political leanings.
62. Hull, Kelley, and Daerr, Intelligence Office, memo; Daerr, Intelligence Office, memo.
63. Mountjoy, memo.
64. 'Minutes of Board of Governors' Meeting, ANL.'
65. Rothbaum, *The Government of the Oil*.
66. Johnston, 'Creating a Canadian Profession.'
67. For a contemporary British account reflecting popular concerns, see Newman, *Soviet Atomic Spies*. See also Turchetti, 'Atomic Secrets and Government Lies.'
68. Wang, *American Science*.
69. Shils (*The Torment of Secrecy*, 186) notes that 'none of the famous scientist spies – Fuchs, Nunn May and Pontecorvo – were American; none of the American spies – Greenglass, Sobel, Gold or Rosenberg – were higher than technicians or engineers'; see Compton, *Atomic Quest*, 117, for similar distinctions and Hewlett, 'Beginnings of Development.'
70. 'The Purge in Britain.' The same month, weeks after Fuchs' conviction, the French government dismissed Frédéric Joliot as High Commissioner of Atomic Energy in France owing to his communist associations. Covertly political, rather than engineering, decisions may have been behind the subsequent French adoption of gas–graphite rather than heavy-water reactors (Hecht, 'Political Designs').
71. Sir Wallace Akers, former ICI manager of the wartime Tube Alloys project, cautiously asked for guidance about the company's attitude; ICI, in fact, 'suggested that it is all to the good for reasonably minded people to become members' (Akers to Perrin, letters).

72. Hawes, 'Far too Secret a Secret'; Fishenden, letter.
73. Skinner, 'Atomic Energy and the Public Interest,' 271.
74. Cockcroft to France, letter.
75. On the American context, see Glennan, 'The Engineer in the AEC.' The two groups remained distinct and mutually exclusive, though. Reflecting the divisions, the Secretary of the Federation of Atomic Scientists proffered that '[engineers] are mostly apolitical, but when they do have views there are of a stereotyped conservative nature' (Meier, 'The Origins of the Scientific Species,' 171). On the distinctive political context of American engineers, see Noble, *America by Design*, which identifies a largely conservative stance allied to corporate interests, while Layton, *The Revolt of the Engineers* identifies a more socially committed progressivist current.
76. For a special issue devoted to the visa problems created by this 'American paper curtain,' see *Bulletin of the Atomic Scientists* 8, no. 1 (October 1952).
77. 'Freedom in Science.'
78. It also incidentally expanded public mistrust to engineers: Rosenberg was an electrical engineer employed during the war by the Army Signal Corps Engineering Laboratory in New Jersey, who obtained Manhattan Project information via his brother-in-law David Greenglass, a machinist.
79. Keys to Editor of *Nucleonics*, letter.
80. Keys to Cockcroft, letters, 17 July and 8 August 1951.
81. 'Atomic energy – Canada – General – US Atomic Energy Commission liaison officer at Chalk River'; Mather, 'Report of Visit to Chalk River Ontario.' According to one staff member there, the roles of the liaison officer at Chalk River and contacts at the US national laboratories included espionage, revealing 'an undercurrent of distrust between the two projects' (Wallace, 'Atomic Energy in Canada,' 128).
82. Manley, 'Secret Science'; Beckerley, 'Declassification of Low-Power Reactors.'
83. Wende, 'Meetings at Argonne'; Woodhouse, 'Brookhaven Fuel Elements.'
84. Wende, 'Visit to Schenectady.'
85. Indeed, personal notebooks had been prohibited during the Manhattan Project, and course notes were similarly classified (Gerber, *On the Home Front*, 45–8).
86. Nichols, *Nucleonics*, 91–2.
87. News item, 'Training Nuclear Engineers at Oak Ridge'; Atomic Energy Commission, 'Oak Ridge Operations Information Manual'; Hewlett and Holl, *The New World*, 184–5.
88. Argonne National Laboratory, *School of Nuclear Science and Engineering*, 3, 9.
89. On the origins of nuclear education, see Johnston, 'Implanting a Discipline' and Herran, 'Spreading Nucleonics.'
90. The *Journal of Reactor Science and Technology* – a classified publication – was disseminated quarterly by Oak Ridge National Laboratory from the early 1950s.
91. Soodak and Campbell, *Elementary Pile Theory*, vii.
92. 'Dana Engineering and Design History – Girdler Corp.'
93. 'Dana Engineering and Design History – Lummus Co.'
94. Eisenhower Administration, 'Project "Candor."'
95. Eisenhower, 'Atoms for Peace'; Eisenhower Administration, 'General Outline for Agronsky Program.'
96. Plowden in Jay, *Calder Hall*, v. In Canada, the expansion of the atomic energy project strained the NRC and led to creation of a new Crown corporation, Atomic Energy of Canada Ltd (AECL) to assume management.
97. Weinberg, *The First Nuclear Era*, 170.
98. Semenovsky, *Conquering the Atom*.
99. Holloway, *Stalin and the Bomb*, 361–2.
100. See early issues for its developing aims: Pinkerton, 'The Institution of Nuclear Energy Engineers'; 'The Birth of the Institution.' Its more frankly profession-oriented stance attracted considerable international membership – nearly half of it from the USA – in the early years of the INucE, unlike the nationally oriented ANS.
101. Abbott, *The System of Professions*.
102. Cockcroft, 'Foreword.'
103. 'Editorial'.
104. 'Another Industrial Revolution?'

105. Cockcroft, 'The Harwell Reactor School.'
106. Hinton, 'Inaugural Address.'
107. 'Special Issue: Secrecy, Security, and Loyalty.'
108. 'Secrecy Wraps Lifted.'
109. Curtiss and Nightingale, 'Trip Report US–UK Graphite Conference.'
110. 'Apology for Impression Possibly Given.'
111. 'The Atomic Scientists Association Ltd: Policy and Associated Correspondence'; 'Atomic Scientists Association's General Correspondence.' See also Hodgson, 'The British Atomic Scientists' Association.'
112. '1960 Minister's Case: Security Clearance for Process Workers.'
113. 'National Union of Atomic Workers 1958–63'; '1961 Minister's Case: National Union of Atomic Workers.'
114. 'Nuclear Engineers and the Trades Unions.' The unions representing INucE members included the Association of Scientific Technical and Managerial Staffs; Technical, Administrative and Supervisory Section of the Amalgamated Union of Engineering Workers the Engineers' and Managers' Association (EMA) and the UK Association of Professional Engineers (UKAPE).
115. Moss, 'The Crisis of Secrecy'; Seidel, 'Secret Scientific Communities'; Galison, 'Removing Knowledge.'
116. Minutes, Board of Governors, 'Tripartite Contract Problem.'
117. Johnston, 'Anglo-Saxon Atom Men.'
118. Commission on Protecting and Reducing Government Secrecy, *Secrecy: Report of the Commission*, xxi.
119. On the relevance of local perspectives over national ones, see Pyenson, 'An End to National Science.'
120. This occupational dimension is relatively unexplored in Hughes, 'Technological Momentum.'
121. Shils, *The Torment of Secrecy*, Sections 2-II and 2-IV.



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