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ARJOMAND, ḴALIL

ARJOMAND, Ḵalil (Khalil Ardjomande; b. Tehran, 1910; d. Tehran, 22 October 1944), mechanical and electrical engineer, professor at the University of Tehran, inventor, and industrialist (FIGURE 1). Arjomand is known for numerous inventions, for founding the ARJ Factory and single-handedly leading it to become a dominant source of technological innovation and modernization in Iran, for his humanitarian actions, and for his role in inspiring a generation of modern Iranian engineers.

Family background, education, and the European years. Arjomand was the son of Raḥim Arjomand and Qodsiya Monajjem. He was named after his paternal grandfather who was, like his maternal grandfather, a respected physician. His father was at one time Acting Minister (*kafil*) of the Post and Telegraph Ministry and, during the negotiation of the Iran-Soviet Union commercial treaty in 1922-23, in Moscow, he was a member of the Persian delegation headed by Sayyed Ḥasan Taqizāda (Taqizāda, p. 90).

Arjomand was educated at Tarbiat School until 1922 and graduated from Ṯerwat (later renamed Irānšahr) High School in 1929. He was then awarded a scholarship for higher studies in Europe, one among the 100 laureates of a competitive examination held by the Ministry of Education, and, on 14 September 1929, he left Tehran for France. Between 1929 and 1932, Arjomand pursued his studies at *lycée*s in Montpellier, and subsequently Grenoble, in preparation for entrance into one of the prestigious Grandes Ecoles (institutions primarily devoted to postgraduate education). Already during this period, his mathematical talent and mental audacity were noted. At the age of

21, in Grenoble, he devised an innovative mechanism for graded motorcar acceleration. This achievement, which prefigures his later creativity, was singled out by Esmaʿil Merʾāt, then supervisor of the Iranian students in France and later Minister of Education, in his reports to Iranian authorities (Bāzargān).

In 1932, Arjomand enrolled at the Ecole Centrale des Arts et Manufactures, in Paris, to pursue a program in mechanical and electrical engineering, and graduated in 1935 with the title of Ingénieur des Arts et Manufactures. At the Ecole Centrale, he conceived, constructed, and tested no less than 11 inventions. These included sophisticated motor mechanisms (for example, a polyphase motor with collector and variable-speed control), speed- and acceleration-regulation mechanisms (for example, a mechanism for hydraulic graded variation of speed), a submersible engine, and an unconventional ironing apparatus. Reports on his inventions appeared in the Iranian press in April 1935 (Arjomand, letter dated 10 May 1935). Upon the advice of his professors and encouragement from the Iranian Ministry of Education, Arjomand decided to file patents. While five among his inventions could not be patented because of already existing patents, at least two, titled *Démarrage des moteurs synchrones monophasés* (Moving Off of Single-Phase Synchronous Motors) and *Régulation automatique des vitesses des turbines et machines motrices* (Automatic Speed Regulation for Turbines and Motor Machines) respectively, were patented on 19 and 20 July 1935, in France. For these accomplishments, the Minister of Education, ʿAli-Aṣḡar Ḥekmat, addressed a personal congratulatory letter to Arjomand (Arjomand, letter dated 7 July 1935).

In recognition of his academic record, the Iranian government granted Arjomand a one-year extension of his scholarship, which he decided to devote to practical training in Berlin. At the end of July 1935, he embarked on a three-month journey that took him through Brussels, Ostend, Cologne, Koblenz, Mains, Wiesbaden, Baden Baden, Stuttgart, Munich, Tegernsee, Garmisch, Vienna, and Prague, and familiarized him with the German language. In November 1935, he started to work for the Siemens factories as an engineer intern, first at the Siemens-Schuckert plant and subsequently at the Siemens-Halske plant. As stated in his letters, by late March 1936 he felt he had absorbed all that the Berlin environment had to offer, and he moved to London in early April to resume his practical training. Arjomand returned to Iran in mid July 1936, well acquainted with the latest Western scientific and

technological developments in his chosen field, and having a good command of French, German, and English.

Arjomand's personal correspondence from his European years illustrates an acute awareness of his own intellectual growth and of his scientific and social surroundings. It also projects the image of a man with independence of mind and a forceful will. He often expressed distress over the general level of education and the absence of adequate reforms in Iran. Reflecting on adversities in life, he wrote in a poignant letter to his parents: "At all events, pure intentions, immaculate thoughts, and integrity in service are the only weapons one may rely upon." (Arjomand, letter dated 29 January 1935).

Academic Career. In 1938, after the completion of his military service, Arjomand was appointed assistant professor (*ostādyār*) in the Faculty of Engineering (Daneškada-ye Fanni) of the University of Tehran. He was promoted to full professorship (*ostād*) shortly thereafter. "In his capacity of university professor," the *Eṭṭelāʿāt* newspaper reported, "Arjomand rendered notable services to the cause of education in Iran and was tremendously appreciated by the academic community of the country" (*Eṭṭelāʿāt*). Former colleagues and students recall Arjomand's uncommon concentration powers, his seriousness in the classroom, and his rigorous work standards (Mozaffar-Zanganeh). His classes attracted large audiences and he was personally loved by his students (Ashraf; Mozaffar-Zanganeh). Arjomand published regularly in science and engineering journals such as the *Majalla-ye ṣanʿat – Nāma-ye fanni va ʿelmi*.

Creation of ARJ. While still a student, Arjomand had been preoccupied with the rudimentary character of Iranian technology and had acknowledged the necessity for fundamental changes. Contrary to the established custom for educated young men to join government agencies, he decided to address his concerns in an independent manner and, during his military service, he conceived and began to design a factory. As the latter would focus initially on metal work, he named it ARJ, an acronym derived from the three Persian words *āhangari* (ironwork), *riḵtegari* (casting), and *juškāri* (welding). ARJ, which means 'value' in Persian, also constituted the first three letters of Arjomand's surname. Arjomand launched this ambitious project, unprecedented in Iran, single-handedly and in parallel with his demanding academic engagement.

In late 1937, ARJ started to operate in a 500-square-meter plant located on

Simetri-e Neẓāmi Avenue, in the west of Tehran near Darvāza Qazvin, with eight workers. The plant consisted of a large workshop equipped with a press, a paring lathe, and milling and arc welding machines. Soon after, Arjomand rented a second, adjacent workshop and arranged for open-air and office spaces. The fabrication processes had to be contrived, any required machinery or tool, down to its most basic elements, had to be designed and constructed *ab initio*, and workers, unfamiliar with modern working methods, had to be trained extensively. In particular, hitherto welding had been restricted to soft metals, since only acetylene welders were available. As an initial step, Arjomand imported two electric welding machines; subsequently, he had ARJ manufacture its own welding transformers (FIGURE 2). This in itself ranked as a notable factor of progress in metal work.

Metal Work at ARJ. The initial output of ARJ comprised large metal and metal-and-glass structures as well as metal parts. In the fall of 1938, the National Bank of Iran (Bānk-e Melli-e Irān) ordered a greenhouse for the ornamentation of its gardens in Tehran. The robust but aesthetic, vast but economically built, semi-circular, metal-and-glass structure fabricated by ARJ became emblematic of the early work of Arjomand. Soon followed additional orders from the National Bank. ARJ manufactured the main gate to its gardens, as well as balustrades and railings for its vault. In collaboration with architect Moḥsen Foruḡi, ARJ produced also metal gates, portals, doors, frontispieces, window frames, and large steel structures for the Bank branches in Ahvāz, Gorgān, Shiraz, and Isfahan. The front portal of the Isfahan building measured 9.5 meters in height and weighed 1,800 kilograms; Arjomand devised an original hinge mechanism which enabled effortless maneuvering. Similarly, he designed the first hinged metallic window frames, as opposed to fixed ones built by craftsmen. A further order from the National Bank was that of a triumphal arch for the wedding celebration of Crown Prince Mohammad Reza. The elegant, metal-and-glass edifice erected at the crossroads of Estānbol and Ferdowsi Avenues contrasted with the traditionally decorated, wooden triumphal arches.

Other metal works of ARJ included large metal structures used in construction, gates, dam sliding gates, portals, balustrades, as well as water pipes, storage tanks, tankers for the transportation of oil and oil-derived products, wheelbarrows, and shovels. In particular, ARJ constructed the brass-ornamented metal portals of the Insurance Company (Šerkat-e Bima) building and those of the Cooperative Company (Šerkat-e Taʿāvoni-e Maṣraf) building.

Moreover, furniture pieces for lecture halls and auditoria, such as replaceable chairs following innovative designs by Arjomand, were manufactured at the request of the Ministry of Education. The Dean of the Faculty of Engineering pointed out that "in his usual manner, here again, Arjomand revealed his mental genius: he constructed something better than that required of him and perfected it beyond expectation" (Bāzargān). In the past, metal products had been either imported or crafted in workshops. The advent of ARJ marked the transition from metal craftsmanship to metal industry in Iran.

Early electro-mechanical production of ARJ. Arjomand extended the activity of ARJ to include electro-mechanical production less than three years into its existence. His first endeavor in this new direction probably consisted in putting together a hydraulic turbine for small scale power supply, near Karaj, along with the construction of an electric mill to which the turbine provided electricity. In 1940, the Ministry of Education ordered from ARJ heating equipments for a series of newly opened schools. Arjomand designed a hot-air-furnace central heating system, for which he had to devise all the necessary components: oil-fired burner, sprayer, storage tank, and centrifugal fan. For the regulated influx of warm air into the rooms, so-called *jalousies à registre* – nickel silver louvers with adjustable slats, that neatly fitted the air-canal outlets – were designed and fabricated. The resulting product was comparable in quality to Western systems. Building upon this work, Arjomand directed the production of more sophisticated central systems for ventilation, heating, cooling, and humidifying, which were set up in a number of public spaces such as cinemas and, notably, in the Fārābi Hospital. Designed for larger spaces, these systems made use, for cooling, of evaporative cooling and, for heating, of water boilers and air-handling units instead of metal foils heated by fuel-oil burners. Heating by means of fuel-oil burners or water boilers in central systems, and by means of oil-fuelled space heaters also manufactured by ARJ, advantageously replaced the prevailing, unsanitary coal-based heating. Yet another ARJ product that contributed to general hygiene was the electric ice-making machine. In Tehran, ice had hitherto been extracted from frozen underground pools and was often contaminated with mud and other impurities. The large slabs of clear, clean ice brought forth by the new machine were sold widely and became famous as '*yaḵ-e kārḵāna-ye ARJ*' ('ARJ factory ice').

Expansion of ARJ and later electro-mechanical production. Within less than five years, the scope of ARJ productions had broadened greatly, a sales center

named Bongāh-e Kārdān had been set up, engineer ʿAli Akbari had become Arjomand's partner, and the number of workers had grown to about 30. In May 1942, ARJ was transferred to a 21,000-square-meter site located on Šuš Avenue, in the southeast of Tehran just outside of Darvāza Ḵorāsān (*ARJ – 1316 tā 1348*; FIGURE 3). The new factory complex comprised a main 2,000-square-meter plant, smaller workshops, offices for design and administration, warehouses, and a staff dining hall. Arjomand's design of the concrete arched ceiling of the main workshop, with its wide span devoid of supporting columns, and its curvature and reduced thickness, was presented as an architectural tour de force in specialized journals such as *Majalla-ye ṣanʿat* (Siavosh Arjomand; Ashraf). It is indicative of both the paucity of available materials and Arjomand's ingenuity that the metal beams used for reinforcing the concrete were in fact discarded train rails, recuperated and bent into the desired shape at ARJ (FIGURE 4).

Problems associated with power and water supplies were serious obstacles. The Tehran power authority did not have at its disposal transformers adequate for converting a 6,000-Volt supply into the required 220 Volts, and the limitations imposed by World War II barred imports. Against general skepticism, Arjomand determined that ARJ itself would manufacture a high-voltage transformer – an exploit in the circumstances. The ARJ transformer was successfully inaugurated in the presence of the president of the Tehran power authority, Maḥmud Ḵalili. As for water supply, Arjomand installed mechanisms to pump, from a depth of approximately 50 meters, the water needed for the operation of the factory. Casting supplemented ironwork and welding, as Arjomand set up an efficient melting and casting workshop, the products of which served ARJ and were also supplied to workshops across the country. Numerous workers, many of them inhabitants of the deprived south of Tehran, were employed and trained. By 1944, their number exceeded 250.

Thus came into being the first Iranian factory complex dedicated to technological production. Agriculture and textile industries, which already existed in the country, were now complemented with a metal and electro-mechanical industry "which became a source of inspiration to founders of diverse industrial branches in Iran" (*Eṭṭelāʿāt*). Indeed, contemporaries of Arjomand have credited him with the initiation of the technological private sector in Iran.

Among the projects carried out in the new plant, possibly the most challenging was the conception and fabrication of various centrifugal pumps (FIGURE 5).

These included both cold-water pumps, used to draw water from wells or cisterns for agricultural and domestic purposes, and hot-water pumps, needed for central heating systems. Later, Arjomand's pumps were used also in fire engines. The one half- to ten-horsepower pumps were constructed according to designs that bore the mark of his originality. In one instance, he replaced the habitual silicon treatment of metal foils, adopted in Western models for the reduction of hysteresis and consequent energy waste, by a chain of heating processes. In another instance, he initiated the study of an ingenious 'floating pump' which was to function unhindered by fluctuations of the water level in wells (Ashraf).

With borders closed to commercial transactions during World War II, ARJ played an important role in providing the country with some of the products no longer imported, which "the Iranian nation greeted with wonder and admiration" (*Eṭṭelāʿāt*). Shortage of enameled copper wire paralyzed the production or repair of electric motors and dynamos, while that of car tires and spare parts threatened transport. With relentless effort, Arjomand led ARJ to produce enameled wire and car tires, two unprecedented enterprises in Iran. For the manufacturing of enameled wire, to begin with, chromite was brought from Khorasan and treated to make firebricks. These served for the construction of high-temperature furnaces in which metal dies were processed. Thick copper wire was extruded through the dies to reduce its diameter. The resulting thin wire was then glazed with a specific mucilage and, finally, wrapped with cotton thread or with silk thread produced in Čālus. For the manufacturing of car tires, every single production apparatus had to be specially contrived and built, including powerful electric motors, furnaces adequate for vulcanizing the rubber, tire molds, and even weaving machines for the layers of cloth to be placed within the tires. Finally, the casting workshop set up in the new ARJ plant provided spare parts for machinery and for trains, trucks, and other vehicles.

All the products described above as well as other items – high-voltage and welding transformers, one half- to 50-horsepower electric motors, machines for mixing concrete, oil-operated water-heating systems, oil-operated torches, car batteries – were manufactured for the first time in Iran, by ARJ. Arjomand's "inventiveness," noted the *Eṭṭelāʿāt* newspaper, "enabled him to produce at ARJ machines and devices, any single one of which would have been sufficient to ensure lasting fame for its creator" (*Eṭṭelāʿāt*).

After the passing of Arjomand, his two brothers, Eskandar Arjomand and

Siavosh Arjomand, perpetuated the existence of ARJ which developed, over the years, into one of the major industrial corporations in the Middle East (see forthcoming entry on ARJ FACTORY).

Humanitarian Endeavors. Arjomand's intellectual quests and achievements were intertwined with his expressed aim of improving the conditions of life of Iranians. War-related restrictions entailed the scarcity of flour and bread, most bitterly affecting the poor. In response to this situation, Arjomand had a large quantity of flour stored in the factory warehouses, and a massive oven built within the factory precincts. Bread baked here was distributed to the deprived families in the south of the city, sometimes by Arjomand in person.

Arjomand also addressed the centuries-old problem of water insufficiency. In collaboration with Maḥmud Ḵalili and geologist and mining engineer Ṣafi Asfiā, he planned the digging of wells which were to be equipped with pumps he had designed and constructed. In his lifetime, at least two such wells were dug in the south of Tehran. For the first time in Iran, electric power was used to draw water. Pipes fitted with accessible taps provided water from the first well, dug within the precincts of ARJ, to the neighboring, densely populated districts. People who hitherto had had recourse only to the insalubrious *jub*s (narrow streams of water trickling down the streets) for their daily needs gained free access to clean water. Subsequently, Arjomand purchased a plot of land in the vicinity of ARJ, where he initiated the digging of a second well for provision of drinking water to the underprivileged population and for water supply to a projected public laundry. Interestingly, even in the method of digging, Arjomand innovated: he replaced the manual extraction of earth with the operation of an electric device. After his passing, Eskandar Arjomand and ʿAli Akbari brought the well project to fruition and a number of wells, equipped with Arjomand's pumps, were set up throughout the city of Tehran.

In numerous instances, Arjomand arranged for visits of medical doctors to the poorer quarters of the city and rural areas, and encouraged voluntary medical consultations and free distribution of required medication (Amir Arjomand). He also instituted, with an initial contribution, a Scholarship Fund at the Faculty of Engineering of the University of Tehran for "students in need of financial assistance" (Arjomand, will and testament, dated 17 May 1943). This fund acquired substantial capital and became a significant means of assistance to students (*Eṭṭelāʿāt*).

Passing and personal traits. "Altruism and succor to others were the principal

ambitions of Arjomand and, ultimately, he offered his life for the realization of those ideals" (*Eṭṭelāʿāt*). On 22 October 1944, he left a family gathering to visit the construction site of the above-mentioned well and appraise the advancement of the project. He had installed an electrically controlled elevator mechanism, which he used for his inspections of the interior of the well. On this occasion, as he was descending into the 36-meter-deep well, a supporting cable broke and, thus, a short, fruitful life of creative work and service came to an end. He was 34 years of age. The news of this tragic death was received with consternation throughout the city. His funeral ceremony was attended by an exceptionally large crowd, including Moḥammad Naḵaʾi, Minister of Commerce and the Arts, ʿAli-Akbar Siāsi, President of the University of Tehran, Mehdi Bāzargān, Dean of the Faculty of Engineering, and more than 3,000 relatives, friends, university colleagues, students, ARJ employees, and anonymous admirers whose lives he had touched. The press covered the event extensively. Numerous commemoration ceremonies were held in his honor, notably that at the Society of Engineers (Kānun-e Mohandesin), during which Raḥim Arjomand, Moḥammad Naḵaʾi, Ḡolām-ʿAli Farivar, President of the Society of Engineers, Mehdi Bāzargān, and Esmaʿil Merʾāt retraced the scientific and moral stature of Arjomand. One of the main workshops of the Faculty of Engineering was renamed "Arjomand Industrial Machinery Workshop" and adorned with a brass bust of his likeness. An elegant monument marked his resting-place at the Baha'i cemetery in Tehran, the Golestān-e Jāvid ('Eternal Rose Garden'), until its demolition in the course of the Islamic Revolution.

Arjomand had married Barazandeh Achraf, daughter of Achraf Achraf – a graduate of French Grandes Ecoles and at one time Director General of the Tehran municipality, later that of the Ministry of Education – and Azizeh Attar, in May 1939. They had three daughters, Mahnaze, Soussane, and Minou, who received degrees in mathematics, chemistry, and physics respectively, from the University of Geneva.

Arjomand is portrayed as one who spent long stretches of time in intense, silent reflection and often expressed awe before the majesty and mysteries of nature (Ardjomande-Achraf). Ever uncompromising, at times even severe, Arjomand was said to dislike idleness above all and he displayed inexhaustible energy in exploring ideas that might push the boundaries of the feasible. His private residence on Taḵt-e Jamšid Avenue in Tehran, designed by him, had such avant-garde plan and equipment that, at the time, many likened it to an

inhabited machine (Siavosh Arjomand). He was an accomplished horseman and skier, using skis with bindings of his own fabrication. Although he "commanded the attention and respect of all" (*Eṭṭelāʿāt*) and "notwithstanding his brilliance of mind and its tangible consequences, conceit and complacency had no place in Arjomand's elevated sphere"; "he was materially disinterested and free from worldly ambitions" (Bāzargān). His contemporaries remarked on his rapidity and accuracy not only in scientific calculations but also in judgments and decisions, on his tenacity in the face of trials and fatigues, and on his moral courage. Close to three decades after his passing, the *Eṭṭelāʿāt* newspaper wrote "Arjomand's name will be immortal [...] in the hearts of Iranians, as a creative scientist, an indefatigable altruist, and a pioneer in the promotion of national industry and national economy" (*Eṭṭelāʿāt*).

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(Rava Azeredo da Silveira)

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