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The Change of Design of the Alyeska Pipeline and Construction Modes in Permafrost Areas, and Their Reasons and the Philosophy behind It

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Abstract: Alyeska had developed or used three major modes in the construction: conventional burial, special burial, and above ground modes. Conventional burial depths of the pipeline top vary from 0.9 to 2.7 m in accommodation to topography, but not soil conditions. Circulating coolant system and/or thermosyphons were equipped for the special burial at the animal passage sections where the pipeline has to be buried. The above ground mode include the pile bent and above ground gravel berms. The later was used only when the pipeline dips into ground and comes out of the ground. The elevated pile bent uses the vertical support member (VSM), with or without thermosyphons. During the initial planning and design phases, the owner companies, the Trans-Alyeska Pipeline System (TAPS), and later Alyeska Pipeline Service Company (APSC), staunchly demanded 100% burial. However, with the progress of survey and elaboration of designs, the construction modes had been changing all the time. When the construction was completed in 1977, only 57% of pipeline was buried, and some experienced engineers prefer 53% of burial after 30 years of operations. The "reasons" for the changes of construction modes include: 1) that they had to change in order to get the permit to cross Federal lands; 2) they performed actual field investigations and participated in the development of the detailed engineering; and 3) National Environmental Policy Act (NEPA). Alyeska was the agent for the seven oil companies, and uncharacteristically, because of the size and costs of the project, the oil companies' engineers individually participated to an unusual extent. In this paper, the authors present the organizational history of Alyeska and the US Federal and Alaska State governments as regards to the construction of the Alyeska Oil Pipeline, the process how the design was evolved and the reasons and the philosophy behind them, and experiences and lessons learned from the Alyeska project.

Key word: Alyeska Pipeline; change of design; construction modes; permafrost; experiences and lessons learned

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Biography: Max Clifton Brewer (1924–), Male, Alaskan, USA, Professor and Consultants on Arctic Environments and Permafrost Engineering, received BS of Geological Engineering at Washington University at St. Louis in 1950, and Honory Doctorate of Science from University of Alaska in 1965. E-mail: maxcbrewer@yahoo.com. Corresponding author: E-mail: Huijun Jin, hjjin@lzb.ac.cn

1 Introduction

The major oil industry companies in the U. S., circa 1970, generally contracted individually for the geophysical surveying; for the drilling of exploratory and/or development wells, for the well site geologists to monitor the drilling of individual wells and for the down-hole geophysical logging and testing; for the construction of facilities, including temporary camps, roads, airstrips, refineries, and pipelines; and often for transportation of the oil via tankers and barges. These are specific, specialized, widely located, intermittent and often seasonal-type jobs requiring widely variable numbers of people. The oil company participation in these activities was usually limited to land acquisition/leasing, providing the planning, including end-product criteria to be met, providing the funds, providing contracting/engineering monitoring for various phases and, in some cases, assigning a quality control engineer/inspector for a particular activity. The oil companies drove hard, competitively bargained for these services, and consciously maintained a high degree of security (secrecy) in the information involved, especially in the geology, geophysical surveys, well-logging and testing. It was the contractors´ responsibility to determine the conditions that one might encounter, to correct any mistakes made (usually without additional funding) in the process of conducting the activity and absorbing any losses incurred in estimating or in unexpected conditions.

The oil companies maintained their own field and formation-mapping geologists; geophysical well-logging and data interpreters; resource estimators; petroleum engineers; lease acquirers/lawyers; cost-estimators; oilfield and refinery operators; sales forces; distributorships; and, in some cases the companies actually owned the oil tankers. These were in-house, full-time company employees and all the information derived/developed was top secret. It was no longer the seat-of-the-pants or wild-catting oil field operations of the late 19th and early 20th centuries. The major oil companies were highly organized, monstrous in size, very powerful financially and politically, only finally coming up somewhat short by the anti-trust law ruling by the Supreme Court of the United States, which broke John D. Rockefeller´s Standard of New Jersey (part of it is now Exxon) into seven parts in 1911. These parts, now separate companies, are very competitive, hence extremely secretive, every penny counts and since they are big and powerful, they are accustomed to getting their own way with relatively weak and understaffed regulatory agencies and with states and other political subdivisions, which are always vying for new industries which they can then tax. The competitiveness resulted in the development of the "culture of secrecy" to a very high degree in the oil companies and has become worldwide for the industry. However, often getting their own way also has tended to make the big companies arrogant as well as conservative, i. e. "if something worked well, why change it?" The lease lawyer´s job was to get leases to drill on private lands (often small land owners or farmers), for permission for pipelines to cross private lands and to hold down complaints about destruction of surfaces/properties, all by the cheapest methods possible.

The discovery well, Prudhoe Bay State No. 1, was announced in March 1968; the confirming well (Sag River No. 1, seven miles (11.3 km) southeast of Prudhoe No. 1), drilled in May-June 1968, confirmed a giant oil field, 24 billion barrels (2.86 billion m^3) of oil in place. Much of the Alaska State-owned area had not been leased and so the Alaska State held a lease sale on 10 September 1969, netting $ 900 million. George Gryc, a geologist from the US Geological Survey, had recommended the area for drilling in the late 1950s. Marvin Mangus and Mickey Lachenbruch had recommended the actual drilling location for Prudhoe Bay No. 1 when they worked as geologists for Richfield Oil before it was purchased by Atlantic Oil Co. In the lease sale, ARCO and Exxon were the big winners on the crest of the structure, Standard of Ohio, later acquired by British

Petroleum (BP), won most of the leases down-structure (along the edges), and four other companies ended up with minor lease holdings. This resulted in ARCO and Exxon getting most of the gas cap (with underlying oil) and BP, being lower on the structure, with less costly leases, getting the major share of the oil.

Alaska State law requires that a continuous field be produced as a single unitized unit for maximum recovery, instead of each company trying to grab off as much oil as it can and as fast as it can. This meant that the seven companies had to agree on a partnership (consortium) and a proportional sharing of the field's production. It was only logical for the consortium to then plan to build the oil transportation system, which it was eventually agreed would be a pipeline, the Trans-Alaska Pipeline Service Co. (TAPS). Since it would cross more than 50% Federally-owned land, almost 50% Alaska State-owned land and a few privately- or native- owned tracts, the lawyers then applied to the Department of the Interior (DOI) of the United States and the Department of Natural Resources (DNR) of the Alaska State for a Right-of-Way (ROW) to cross those lands with an 1.22-m-diameter pipeline carrying 60 ℃ oil.

However, then the oil companies' consortium's standard ways of doing business began to unravel.

The DOI requested the U.S. Geological Survey (USGS) to comment on the permittee's (TAPS) plan. The USGS (George Gryc, with geologists who had studied nearly all of the proposed ROW over a period of 25 years) took strong issue with the plans that only 64 km, all on the North Slope, would be above ground, that the other 1,223 km (95%) would be conventional burial, except for crossing the torrential and mighty Yukon River, stating that TAPS was ignoring the danger to the pipeline posed by permafrost, and specifically mentioned the ice-rich, warm permafrost in the Copper River Valley in the South-Central Alaska[1]. The USGS cited this as an example of potential permafrost problems; TAPS appeared to interpret the Copper River reference as the main bad permafrost area.

On 1 January 1970, President Richard Nixon signed the National Environmental Policy Act (NEPA). Among its requirements were that the cognizant federal agency must prepare a Final Environmental Impact Statement (FEIS) when a project could significantly impact the environment. It also established certain criteria for protection of the environment[2]. Another portion of NEPA allowed landowners or organizations trying to protect the environment, or potentially affected by the project, to sue for relief in US Federal Courts. TAPS was the first significant project to encounter the requirements of NEPA and this introduced many uncertainties for the companies, and for the governmental agencies involved in permitting or regulating the proposed activities. The environmental organizations, who generally opposed the project, also found their opposition to construction of the pipeline to be an excellent recruiting advertisement for new memberships.

The Alaska native organizations, which had neither been conquered nor had sold their lands when the U.S. acquired Alaska from Russia in 1867, had been trying to get a land claims settlement for several years. They promptly sued because the ROW would cross lands that they claimed. In effect, they were holding pipeline construction hostage for settlement of their land claims. The US Supreme Court issued an injunction prohibiting construction until settlement of the suit. A number of environmental organizations also sued.

These factors introduced great uncertainty in the pipeline scheduling.

2 Organization of TAPS, Alyeska and Management of the Trans-Alaska Pipeline Project

TAPS, prior to 8 May 1969, had already ordered 1,287 km (800 miles) of 1.427 cm and 1.173 cm wall thickness, 1.22 m diamter pipe from Japan, since no U.S. steel plants were then designed to produce that diameter pipe. The pipe

was designed for a maximum operating pressure of 1,180 psi (8.1 MPa) and a rupture pressure of 1,638 psi (11.3 MPa), assuming a maximum pipeline throughput of 1.8 million barrels per day (Mbpd) (or about 2.48 $m^3 \cdot s^{-1}$), later increased to 2.0 Mbpd (about 2.76 $m^3 \cdot s^{-1}$). Thus, TAPS was effectively "locked in" before they had even a preliminary construction design, and before they had information concerning the permafrost or other conditions along the proposed route or how these conditions might impact the pipeline or its construction. The initial pipe shipment began arriving at Valdez, Seward and Prudhoe Bay during the summer of 1969, and TAPS had freighted equipment and supplies from Fairbanks to Prudhoe Bay the following winter planning to begin construction of the pipeline in 1970. ARCO, BP and Chevron (previously Standard Oil of California and a minor owner of leases) had already begun drilling development wells.

However, construction was now on hold and TAPS began to assemble the information and to develop the preliminary designs that the DOI would need to write the Draft EIS and the FEIS, the DOI began to hold public hearings on the project as required by the NEPA, and the US Congress began working on a Native Land Claims Settlement Act.

The TAPS initial submission of information, using some 20 consultants´ reports, such as that of Pearn (1970)[3] generally only generalized plans[4], to the DOI in the spring of 1970 was deemed to be grossly insufficient in its treatment of the permafrost problems, and incomplete for the DOI to write a credible FEIS. The consultants´ reports also were criticized by a separate reviewer as being internally inconsistent and inconsistent one with another. The owner companies then reorganized TAPS into a new entity, Alyeska, on 27 August 1970. With the estimated costs of the project rising sharply, the owner-company engineers and geologists also began to assume a more active role in the field investigations along the proposed route and in the actual design of the pipeline.

The initial estimate of costs had been $ 900 million; $ 1 million/mile for the pipeline (twice the average costs in 1970 of constructing a buried pipeline in other (non-permafrost) areas, plus $ 100 million for the terminal and storage tank farm at the ice-free, deepwater port of Valdez. That estimate had not included the costs of construction of the processing (scrubbing) plant (to remove the sediments, natural gas and heavy hydrocarbons, water, CO_2, N_2, and helium) at Prudhoe, or the costs of detailed engineering investigations of permafrost and the subsequent amelioration thereof, as well as the costs of the bridge carrying the pipeline to cross the Yukon River or the haul road to Prudhoe (Dalton Highway) at $ 310,000/km. One of the major oil companies, Humble (now Exxon), still held out for consideration of a tanker route from Prudhoe through the Northwest Passage (the Manhattan Project)[5] even though the tankers could not come closer to Prudhoe than 50 km, due to the shallow water, and that the intervening distance would be ice covered and subject to ice scour for 9 to 10 months of the year, 12 months in 1975.

Meanwhile, the DOI had recognized that it would need to be more heavily involved in aspects other than geology and permafrost, and had organized a "Menlo Park Working Group" (MPWG) (George Gryc as leader), composed of specialists from other agencies such as the USGS, Water Resources, Pipeline Safety, Corps of Engineers, Coast Guard, Weather Bureau, EPA, Bureau of Standards, U.S. Fisheries and Wildlife, to consider pipeline corrosion and safety, permafrost, earthquake and stream hazards, debris and avalanche hazards, and the biological environments. By summer 1972, Alyeska was still insisting that a maximum of 18% of the pipeline would be above ground, although in the final analysis 53% was built above ground. Meanwhile the Alaska State had, on 1 July 1971, created the Department of Environmental Conservation (DEC), with Max C Brewer as the first Commissioner, to protect the air, water and lands of the Alaska State, although

the provision of stipulations relating to leasing of lands remained the prerogative of the DNR.

The Native land ownership issue/suit was settled by passage of the Alaska Native Land Claims Act by the Congress on 2 December 1971, but the environmental organizations´ suits continued to thwart issuance of a permit for construction until resolved by the US Congress[6]. That issue was resolved on 16 November 1973, the required DOI ROW issued on 23 January 1974, and construction work began on 29 April 1974.

The Trans-Alaska Pipeline Service Co. (TAPS), a partnership, was organized in 1968, with ownership and shared costs of 37.5% by each ARCO and BP and 25% by Exxon[7]. Each company had its own urgencies/agenda in getting the oil to market; ARCO and BP having the greatest urgencies, Exxon less so still hoping to tanker oil through the Northwest Passage to the east coast of the US. The four minor owners of the Prudhoe Field leases did not have ownership shares in the proposed pipeline. The TAPS decision was made by a committee, the least efficient and usually least cost-effective way.

Two modes of construction (each would later have modification such as special construction, bridging) of the proposed pipeline were announced: 64 km, mostly on the North Slope, above ground and the remaining 1, 223 km with conventional burial. Some even proposed a railroad and one even an overhead tramway. TAPS then very roughly selected the proposed routing and applied for the required ROW to cross the lands involved, and for the leases of minor acreages upon which to establish construction during the summer of 1969.

The lands to be crossed were nearly all owned by either the US Federal or the Alaska State governments. The Federal lands were owned by the DOI and managed by its Bureau of Land Management (BLM); the Alaska State lands were managed by the DNR of Alaska State. The Secretary of the DOI, Walter J. Hickel, who was the former governor of Alaska and with a very pro-development record, had received rough confirmation hearings by the U.S. Senate and, to satisfy critics and partly for cover-your-ass(CYA) purposes, asked the USGS to comment on the TAPS permit application. The USGS responded that the TAPS reflected a lack of understanding about permafrost and that burying 95% of the pipeline would result in a disaster. The passage of the NEPA then intervened. The Alaska State DNR routinely issued its required permits, upon the payment of nominal rents for the lands involved, and without the ROW on Alaska State lands being limited to the 100-foot (30.5-m)-width as required by the Federal Minerals Leasing Act.

TAPS then submitted their consultants´ answers to the USGS complaints about their lack of understanding about permafrost. When those answers were deemed insufficient and the DOI determined that much more information would be needed to write the DEIS and FEIS, it created the MPWG. The TAPS Committee recognizing that the requirements from the MPWG were going to escalate, in June 1970, hired Ed Patton, who did not even move to Alaska until April 1974, as the TAPS manager, and created a new company, Alyeska, in August 1970 to take over the TAPS responsibilities. It was something of a "shell game" as TAPS had accumulated a lot of adverse public relations. However, the oil companies continued their parsimonious ways of just giving the new Alyeska, with Patton as president, enough funding to answer the MPWG requests for information, and often having to also furnish engineers on leave from the parent companies to provide the information. It is noted that the oil companies were psychologically still planning to dig and bury, placing a minor amount of the pipeline on supports, spending as little money as possible until they had the construction permits in hand, and then engineering as construction progressed the same way as the industry had done historically. They considered the information requests from the MPWG, the requirements of the NEPA and generally from some environmental agencies to be an unnecessary

burden. Alyeska did not divulge any more information than was requested (culture of secrecy) and did not even provide a project description, which further complicated drafting of the EIS, until August 1971. They did not hire a senior project construction manager, who would be in charge of all construction, until September 1973, two months after the US Congress had passed the Trans-Alaska Pipeline Authorization Act authorizing the DOI Secretary to insure the necessary construction permits. Alyeska delivered the plans, engineering drawings and the written specifications for the pipeline in late May 1974. Construction actually started six months after it had been fully authorized and while consultants´reports were still arriving.

For four years late (from late 1969 to late 1973), the MPWG composed of representatives from multi- agencies from numerous Federal Departments and headed by George Gryc, had been the principal actor for the Federal Government at a cost of about US$ 12.3 million. The MPWG had badgered Alyeska for information/data, often having to conjure up how they might cross critical areas, in order to complete the FEIS in six volumes and, more importantly, to write the detailed "Stipulations for Construction" which then became an integral and legal part of the Agreement between the DOI and the seven oil companies. The "Stipulations" had the force of law, but unlike regulations, could be modified by knowledgeable monitoring personnel to accommodate the unforeseen conditions that were bound to arise, especially with a major project traversing hundreds of miles of relatively unknown country. However, the DOI´s BLM, the land owner which had been busy with surveying and land transfers, now had the responsibility for monitoring the construction of the pipeline, although not the oil-gathering lines leading up to the pipeline. The latter all were on Alaska State property.

The DOI Secretary appointed Andrew P. Rollins Jr., a retired brigadier general in the U. S. Army Corps of Engineers, to be titled "Authorized Officer" (AO) to head the BLM monitoring group in January 1974. Mr. Rollins immediately hired a consulting firm, Mechanics Research, Inc., to serve as consultants on engineering and environmental matters and it, in turn, subcontracted those responsibilities to two other firms: Gulf Interstate Engineering and Ecology and Environment, Inc.

3 Critiques and conclusions concerning the construction of the Alyeska Pipeline

The Alyeska Pipeline Project was, and is, politically very controversial and hyperbole in the extreme has been employed by both sides in the controversy.

The public feels at a disadvantage and instinctively doesn't trust "bigness" in companies that are crucial to their welfare. Encouraged by the media and by history, they consider oil companies to be untrustworthy and arrogant, rape, ruin and run companies, inconsiderate of the environment, and exploiters rather than developers of resources. The regulatory agencies, be they US Federal, Alaska State or local (municipality and others), tend to reflect those attitudes (from their constituents), and even take advantage of those fears in the hope of increasing their budgets.

The major oil companies are very competitive, have a culture of extreme secrecy which extends to many aspects and activities where there is nothing to be gained by secrecy. They also have a strong aversion to any regulations and to regulatory agencies.

The Alyeska Pipeline is an elongated project located in the Arctic, with a variable, challenging, often harsh, and unforgiving environment, that was new to the oil companies especially as regards the construction of a major pipeline. The area had, and has, a poorly developed infrastructure and very limited transportation system/possibilities, and hence the proposed activities required an unusual degree of planning.

The land ownerships were subject to question due to the overdue resolution of the Native Land

Claims which had been in abeyance for almost a century. A resolution was required before the project could be initiated.

The passage of the NEPA intervened in the middle of the controversy. Whereas it is well-intended and has many advantageous aspects, NEPA also is a legal nightmare which could be used by lawyers and the courts to obfuscate the real problems/effective solutions/compromises required in the completion of the pipeline. It was unfortunate that the regulatory agencies and industry had to go through the "learning curve" to develop case law, to interpret and to develop basic procedures for its implementation on the largest project underway in North America. In effect, they were both dumped into the middle of the river and then told to learn to swim.

There were two major land owners, but it was one pipeline, and a single unified authorizing/construction monitoring entity should have been provided. In actuality, there are four parts to the Trans-Alaska Oil Transportation System: 1) Pipeline and its associated infrastructures such as pump station, access road, and others; 2) the Prudhoe oilfield gathering lines/oil scrubbing plant, 3) the Alyeska Pipeline storage tanks at Valdez, and; 4) the marine tanker system. The Alyeska Pipeline Authorization/Construction Stipulations were applicable for only item 3.

The "Planning Period", 1969—1973, created by the Settlement of the Native Land Claims issue, the legal machinations in determining procedures for operating under the NEPA and the political controversies, was grossly underutilized by Alyeska, and, to a large extent, also by the US Federal and Alaska State agencies that would ultimately have authorization/monitoring responsibilities. Thus, these groups were unprepared and were not properly staffed with knowledgeable, field-experienced personnel for their responsibilities when the "TO PROCEED" authorization was granted and, in actuality, for many months thereafter.

With the authorization "TO PROCEED," there came an almost "changing of the guard."

Alyeska employed a senior construction manager, Frank Moolin, experienced in elongated construction projects, and was the project manager at the Fort wainright, Alaska. This is a field-type job, not just looking-out-the-office-window-and-pushing-paper-type job. He found that he had to organize the project from the ground up, including designing camps, determining equipment and supplies needed and arranging transportation and scheduling. Alyeska also employed a construction consultant, Bechtel Corporation, but still was at a loss in telling them what they were employed to do. Alyeska moved its headquarters from Bellevue, Washington, to Anchorage, Alaska, in April 1974.

The DOI replaced the MPWG of senior researchers/engineers, with many years Alaskan field experience and who had prepared the FEIS and developed the pipeline construction stipulations, with its land manager, the BLM which had had only a marginal role in discussions leading to preparation of the FEIS or developing the stipulations. The DOI also employed a retired brigadier general, U.S. Army Corps of Engineers, as its authorizing officer (AO). The AO immediately hired a consulting firm as consultants on engineering and environmental matters which in turn subcontracted those matters to two other consulting firms, none with known Alaskan experience and none of whom had previously participated in the Alyeska Pipeline Project.

The Alaska Governor appointed Charles Champion to be the Alaska State Pipeline Coordinator (SPC), to the chagrin of the State´s Land Manager (DNR) whose candidate became the Assistant SPC in charge of administrative duties. Champion, who had participated with Alyeska engineers for the past 18 months and was experienced in the oil industry in Arctic Alaska, preferred to employ individuals with Arctic experience in preference to relying on employing contractors. In many ways, the Alaska State, which earlier had been a junior partner to the DOI, now became more of a senior partner in monitoring the pipeline

construction.

The Joint State/Federal Fish and Wildlife Advisory Team (JFWAT) was advisory only. This was a necessity in a major, fast-moving construction project which cannot proceed with multiple supervisors, but did not promote a team, can-do spirit.

Due to a lack of advanced planning (Alyeska had still planned to dig and bury, engineering as they progressed), insufficient field investigations (particularly of permafrost conditions, soil and bedrock conditions, and borrow-pit quality), and inexperience working under Arctic conditions, there were more reconstructions, relocations, replacements and re-doings of sections of the pipeline, and more change orders than normally would have been expected.

There were multi-layers of quality-control inspectors, Federal contractors and subcontractors to the pipeline construction and to environmental protection. The applicable stipulations often were applied word-for-word as regulations by personnel, without the knowledge of how or why they were developed, rather than as guidelines of intent to be used by knowledgeable personnel when unforeseen conditions were encountered. An example was the prohibition of taking gravel from a stream, because it might be harmful to fish spawning, even though the stream was too shallow for spawning without the fish eggs freezing or where the gravel bar was exposed, and demanding the use of crushed rock, the sharp edges of which would damage the protecting coating of the pipeline. These problems were exacerbated by the rotation of monitoring personnel without the overlapping of their schedules.

Sometimes Alyeska over-promised what they could perform or produce, for example the "smart pig" to inspect the integrity of the pipeline. The "smart pig" still hadn't been developed a year after oil started flowing in the pipeline. Other examples were: 1) refrigerating around piling (okay around a building), but impractical, if power is required, around piling/supports beneath the pipeline. Thermosyphons, using "nature's cold", provide a practical method for protecting pipeline supports, but needed consideration of the environment (permafrost) to be protected rather than being a "cure-all", and 2) the "null" cathodic protection which also requires a power source.

Excessive costs also were incurred by over-regulating in protection of the pipeline/environment. This was addressed, as regards welding inspection, by the SPC in his final report. It also applies in numerous cases where the inspection/monitors followed the "pipeline stipulations" word-for-word, rather than intent, and understanding the "whys" behind the stipulations.

The multi-story scrubbing plant (not part of the Alyeska construction) at Prudhoe was constructed on a lake that had been drained and then filled with gravel. The permafrost no longer existed in the upper tens of feet beneath the drained basin of the lake, and this construction was an innovative way of solving the need for a stable environment.

The controversy between constructors/environmental protection advocates should have ended once the US Congress authorized and mandated that the DOI Secretary issue the required permits. The project should then have been a common goal to accomplish the best job possible. A team effort by the engineers and the environmentalists to solve the problems, as Max C. Brewer testified in the public hearings in Fairbanks in 1970, was required instead of the "cops and robbers" running battles that ensured. The media also should have provided objective news coverage instead of exaggerating problems in order to gain headlines.

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阿拉斯加输油管的设计和施工方式方案变更过程及其背后的原因和哲学思想

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摘　要:: 阿拉斯加输油管道公司曾经研发和使用了3种主要施工方案和技术: 传统地埋式、特殊埋设和地上敷设方式. 在传统地埋式施工方案中, 管顶埋深变化于0.9~ 2.7 m. 这主要是考虑了地形变化, 而不是沿途的岩性和土壤类型. 在特殊埋设方案中, 在原油管道必须埋设的地段, 如大规模动物迁徙常用地段则使用通道冷液循环降(保)温系统和(或)热管(桩)降(保)温, 来保护多年冻土. 地上敷设方案包括桩基架设和地上洁净砾石管堤(垫护层). 后者只在管道进入和离开多年冻土时采用. 架设桩基横梁方案中使用有或没有热管保温的垂直支架梁(单元)(VSM). 在初步规划和设计阶段, 管道的业主公司(即横穿阿拉斯加管道系统, 或TAPS)和随后的阿拉斯加管道服务公司(APSC)不容商量的坚决要求100%的埋设方案. 但是, 随着勘察工作的进展和设计方案的细化, 施工设计方案在不断变化. 1977年管道施工结束时, 只有57%的管道采用了埋设方式. 管道运行30 a后的今天(考虑运行期间维护中所产生的问题), 很多经验丰富的工程师认为53%的埋设可能更合理. 设计和施工方案变更的原因主要有: 1)为了获得通过联邦政府所属的土地所需的许可证, 政府有特殊的规定和要求; 2)管道公司的设计、施工和管理人员进行了现场野外调查、研究, 并积极参与了详细设计和研发; 3)美国环境政策法案(NEPA)的最新要求(启用了核准制). 阿拉斯加管道服务公司是7家主要石油公司的服务机构. 由于这个项目的巨大规模和所涉及的高昂费用, 致使各大石油公司的工程师非同寻常程度的参与. 在文章中, 笔者论述了与阿拉斯加管道施工有关的阿拉斯加管道服务公司、美国联邦和阿拉斯加州政府相关组织机构的形成历史, 管道设计演变过程及其背后的哲学思想, 以及阿拉斯加管道工程项目的经验和教训.

关键词: 阿拉斯加输油管道; 变更设计; 施工方案; 多年冻土; 经验教训
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