America’s Greatest Projects and their Engineers Vol-III

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The Alaska Pipeline

This course is a synopsis of the design and construction of the Alaska Pipeline, a mid-twentieth century project that overcame severe weather conditions and was on the forefront of unique engineering technology. This course details the contributions of the engineers, workforce, manufacturers, and contractors and their remarkable achievements.

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Introduction

While many of our greatest American projects were conceived by the federal government as a means of national security or growth, the private industrial sector occasionally entertained a project that would provide a measure of national security and also prove to be profitable. One such project was the Trans-Alaska Pipeline, an 800-mile long, 48-inch outside diameter pipeline system that pumps crude oil from the North Slope at Prudhoe Bay south to the terminal at Valdez, Alaska. Following the oil embargo of 1973 and the experiment with price controls on everything from pizza to most commodities, long lines of automobiles formed whenever the word got out that a certain gas station either had received, or was about to receive, a tanker truck full of gasoline, and grade was irrelevant.

A. Initial Project Activities

1. Major Oil and Gas Reserves Are Discovered

The natives of North Alaska as well as those who operated in those areas such as whalers and fishermen always recognized the seepages in those lands as some form of petroleum. As the economy of the United States developed in the post World War I era, our country became very dependent on a stable oil supply. Accordingly in the early 1920's President Warren Harding had designated an area in northern Alaska as one of four future oil reserves, due in large part to the fact that the U. S. Navy was converting their fleets from coal-burning to fuel oil..

During World War II the U. S. Navy had funded oil exploration, and several surveys were made to determine the extent of oilfields in Alaska, but the navy terminated the program in 1953 as the first nuclear submarine was being commissioned. These reserves lay largely dormant, even after World War II, as other sources of energy, particularly nuclear, became popular. In fact, nearly all of the one hundred nuclear power generating plants in the United States were either built or in the process of being developed between the period between the end of World War II and 1973.

However, Richfield Oil Company drilled an enormously successful oil well in northern Alaska in the late 1950's, which became the first oil field in commercial production. Know as the Swanson River Oil Field, it spurred the development of others, so that by 1965 at least five oil fields were in production. The obvious conclusion was that the areas north of the Brooks Range, which is actually above the Arctic Circle, would contain vast amounts of oil. In 1967 the Atlantic Refining Company and their new partner Richfield Oil Company began surveying and exploring for oil in the Prudhoe Bay area. In March of 1968 the new company (ARCO) drilled a well that began producing over 1,000 barrels of oil per day, and in June of that year drilled a second well that was producing oil at a similar rate. This newest oil field confirmed the existence of a mammoth oil reserve in Prudhoe Bay. The geological estimate was that this new oil field contained more than 25 billion barrels of oil, making it one of the largest oil fields in the world.

Ways to Transport the Oil

The problem as ARCO envisioned it was not so much developing the oil fields in the harsh conditions and environment, but rather how to get the product to market. A pipeline connecting the rich oil fields on the North Slope of Alaska to the ice-free port in the south at Valdez was one of the first considerations, but no oil pipeline of the length being proposed had yet been constructed. Boeing Corporation had proposed the RC-1, a gigantic 12-engine tanker aircraft, which would have needed extremely long runways for takeoff and landing. General Dynamics had proposed a group of submarine tankers, probably nuclear-powered, in order to travel under the Arctic ice cap. Still a fourth proposal was to extend the Alaskan Railroad from Prudhoe Bay to the Valdez Area. Humble Oil even sent an oil tanker specially fitted with an icebreaker bow and powerful engines and propellers to plow through the ice-laden Arctic Ocean surrounding Prudhoe Bay, but its cargo hold suffered severe damage even before it arrived in Prudhoe Bay, necessitating extensive repairs before it could be rerouted.

In October 1968 a joint group made up of Atlantic-Richfield (ARCO), Humble Oil (Esso, or Standard Oil of New Jersey, which became Exxon in 1972), and British Petroleum (B/P) were formed. The three companies, moving swiftly in anticipation that approval of the drilling for oil and the construction of the oil pipeline would be a foregone conclusion, formed a task force of representatives from the three companies. The group was initially made up of executives, operators, and engineers and was known as the Arctic Task Force. Meeting as often as three days a week, they concluded within a few months that the only viable option seemed to be a pipeline running from the northeast corner of Alaska at Prudhoe Bay almost due south for a distance of approximately 675 miles to Valdez, the northernmost ice-free port in Alaska. Once the Arctic Task Force concluded that a pipeline would be the only viable option, the group was whittled down to a smaller group of engineering representatives from each company with the responsibility for developing the pipeline design and specifications.

Then known as the Trans-Alaska Pipeline System (TAPS), the TAPS Task Force proceeded to prepare all inclusive specifications for a pipeline that would carry enough oil to allow the three companies to achieve their return on investment within three years from startup. The initial estimated cost of the project was established at $1.5 billion. The mathematics and the throughput objectives gave the engineers the result that a 48-inch outside diameter pipeline with a wall thickness of about 1/2 inch would be required, and that the only viable producers of that type of pipe would be the manufacturers of SAW (Submerged Arc Welded) pipe.

Originally hoping to begin laying pipe by September of 1969, TAPS believed that substantial orders had to be placed in advance for the pipe, since time was of the essence. Although the optimum size of pipe needed for the projected oil flow across Alaska was determined by TAPS to be 48 inches in outside diameter, at that time there were no large diameter pipe mills in the United States or Canada that could satisfactorily produce more than 36 inch diameter, SAW pipe at anywhere near the rates of production that would be need for an estimated 800 mile long pipeline. Furthermore, there were only a few large diameter pipe mills in the United States or anywhere else in the world that could properly tool up for even 42 inch outside diameter SAW pipe.

After some delay due to necessary planning, TAPS had submitted a formal plan In June of 1969 to the Department of the Interior which included the pipeline routing accompanied by a 100 foot right of way. Also included in this plan was a request for an additional 100 foot right of way for the construction of a maintenance and supply road that would run parallel to the pipeline. The reason for the 100 foot right-of-way was never really fully explained until now, but review of the company's early records reveals that the obvious plan by the three original oil companies was to build a separate natural gas pipeline running parallel to the oil pipeline.

The oil companies believed, rightfully so, that there would be billions of cubic feet of natural gas in the Prudhoe Bay oil fields. Consequently, they had charged their Task Force with planning a quiet, unpublicized program to develop a natural gas pipeline simultaneously with the oil pipeline. Unfortunately for American consumers the controversy over the oil pipeline became so contentious and political that the natural gas pipeline concept was eventually placed on the "back burners" (more on that later). The Alaska Pipeline Task Force, which gave way to the Alyeska Task Group, continued to explore the concepts of a natural gas pipeline while concentrating most of their efforts and resources and attention on the oil pipeline

2. Securing/Storing the Pipe

Pipe Manufacturing

Once the TAPS Task Force had drawn the conclusion that 48-inch outside diameter pipe would be needed for the oil pipeline, they set about scouring the world for manufacturers of such a product. They knew that spiral welded pipe would not stand up under the harsh conditions of the Alaskan environment, and determined that there was the necessity to find a UOE pipe manufacturer who could provide the 48-inch SAW (Submerged Arc Welded) pipe.

NOTE: UOE stands for U-Press, O-Press, Expander. The process involved:

1. the rolling of a relatively high-strength (X-52 or greater) steel plate, approximately 1/2 inch thick by slightly over 150 inches wide by anywhere from forty to sixty feet in length,
2. processing the raw plate through a planing machine to give the butting edges on each side of the plate a smooth surface, while at the same time cutting a 30° bevel on the top and bottom edges of each side of the plate to permit consistent inside and outside welded joints.
3. crimping (turning up the side edges of the plate) each side of the plate at about a 22 1/2° angle,
4. conveying the crimped plate into a U-Press, which had 48-inch inside diameter rounded bottom dies and a u-shaped anvil that would lower and create a half round when lowered to the bottom,
5. conveying the half round plate into an O-Press which had 48 inch top and bottom dies and created a fully rounded shell when the top dies were lowered.
6. conveying the rounded shell with the outer edges pressed together, through submerged arc welders on the inside and outside diameters (at that time by two-wire welders each, one for the root pass and one for the crown pass),

7. end facing the ends of the pipe ("cans") to provide a squared end surface while simultaneously adding an outside bevel to allow for uniform joint welding in the field,

8. mechanically expanding the welded "cans" in three to four foot increments in order to give the pipe its final outside diameter and roundness, and to also add metallurgical strength to the pipe.

Task Force Seeks Suppliers

With the anticipated construction to begin on some portion of the pipeline in September 1969, even though surveying was far from complete, the TAPS Task Force issued a pipe specification to several foreign and domestic UOE manufacturers. The three principal engineers who developed the pipe specification were:

1.	Rado Loncaric	Atlantic Richfield
2.	Edgar Von Rosenberg	Esso (Exxon)
3.	Harry Cotton	British Petroleum

Beginning in late February of 1969 Loncaric and Von Rosenberg began to review proposals and to visit the plants and mills of the many companies around the world who were interested in supplying the 48-inch O.D. pipe for the oil pipeline. TAPS made a concerted effort manufacturers of 48-inch O.D. submerged arc welded (SAW) pipe in the United States and Canada. The reality was that there were none anywhere in North America, or even Europe, at that time. The Task Force (primarily Von Rosenberg) visited plants at Napa and Kaiser Steel, and discussed the specifications with numerous U. S. SAW manufacturers such as Bethlehem Steel, Kaiser Steel, and U. S. Steel. Most of the SAW domestic producers proposed 36-inch O.D. pipe, or 42-inch O. D. pipe as alternatives (only two or three companies in the United States actually had the capability to produce up to 42-inch O.D. pipe at that time), but no U. S. manufacturer was willing to make the investment to go to 48-inch unless they were assured of a purchase order.

In April of 1969 Von Rosenberg traveled to Germany to review a proposal by Hoesch and to visit plants at Mannesmann and Thyssen. While Hoesch was willing to make the investment in their plant to convert to 48-inch O.D pipe, their asking price per ton was considered too high by Loncaric (Von Rosenberg agreed), and their proposal was rejected. Von Rosenberg later flew back to England and visited British mills at the request of British Petroleum, but with the same negative results. While in London he communicated his findings with Harry Cotton, B/P's member of the TAPS Task Force, and Cotton's boss Phil Ford. Cotton, who was being promoted to Chief Engineer of BP and was about to be transferred to New York, related to him that the necessity for a pipe purchase was very near, and that the Japanese seemed to be the only ones who would meet the specification and the price and were willing to make any investment necessary to produce 48-inch O,D, pipe.

Believing that they were running short on time, the TAPS Task Force visited Japan and discussed the likelihood of issuing contracts to the three manufacturing/trading companies that had submitted the lowest proposals. The strong selling points to the members of the Task Force were:

1. the Japanese mills seemed willing to invest in the 48-inch mills without a firm commitment.

2. the Japanese mills would be able to provide their pipe in longer lengths between forty and sixty feet, whereas the U. S. and European mills could have only produced forty foot lengths.

Sumitomo Metal Industries had three major manufacturing plants, and was well-known following World War II for its ability to produce oil country tubular goods OCTG) such as seamless pipe and tubing. Sumitomo was both a trading company and a manufacturer, and was given a contract in July of 1969.That contract was followed by a commitment to purchase pipe from Nippon Steel, which owned Yawata Works and Fuji Iron & Steel, two of the largest steel plants in Japan. The other contract went to the trading company of Nippon-Kokan, who represented several steel manufacturing facilities in Japan, including Kabushiki and Kaisha. They all agreed to supply the 48-inch outside diameter submerged-arc-welded pipe with wall thicknesses of about 1/2 inch per the TAPS Task Force specification. With Von Rosenberg and an ARCO representative present, Sumitomo rolled the first plate on 01 August 1969 for inspection and testing. After impact tests and tensile tests proved satisfactory, Sumitomo began full plate and pipe production the next day.

Pipe production began at Wakayama Works on 15 August 1969, but the first three pipe produced were unacceptable and were rejected by Von Rosenberg. Welds were rejected due to the edges of the plates being ragged and the bevels being inconsistent. In addition there was a problem at the expander that created an out-of-round condition. Following lengthy improvements by the Japanese, which resulted in the engineers staying at the pipe mill for twelve to sixteen hours the next few days, the changes proved to be very effective. The pipe coming off the mills was excellent quality, the adjustments to the welders worked very well, and the x-rays looked good. The Task Force then visited Yawata Works, and some arguments ensued because the Yawata management did not want TAPS personnel to tour the plate mill. This issue was peacefully resolved and the group, in full safety gear, was later permitted to visit the mill and were well received. Also during this period of time the Task Force visited several foundries and forge shops in an effort to determine the Japanese capabilities for flanges, fittings, and other castings and forged materials needed for the pump stations, but were not impressed with any shops that they visited.

Occasionally one of the actual manufacturers such as Yawata Steel or Wakayama Steel would try to circumvent the specifications. Whenever the Task Force would become aware of a practice that did not meet their strict specifications, they would come down hard on the Japanese pipe producers as well as the trading company hierarchy. Von Rosenberg, who stood six feet six inches tall and towered over the shorter Japanese by a foot or more), was an extremely imposing figure. Furthermore, he weighed over 270 pounds (he later lost more than forty pounds), and as a result proved to be particularly intimidating. "Tiny", as he was affectionately known by his peers and Esso executives, was so knowledgeable of the welding practices and non-destructive testing procedures, that he rarely accepted any variance on the pipe specifications. While at Sumitomo for a return inspection on 29 August 1969, the team saw the first shipment of pipe headed to Alaska. The Alaska Marvel had four holds, each stacked with pipe that were ten high, and holding a total of 1,180 pipe. The Task Force returned from their latest trip to Japan on 31 August 1969 not realizing that, although they had done their job, the future of the Trans-Alaskan Pipeline Project would soon be in the hands of their lawyers and the United States government.

At that time the price tag of $100 million for the estimated 800 miles of pipe seemed to be excessive, but in hindsight proved to be one of the best bargains of the entire project. Each pipe weighed an average of 7.5 tons and cost less than $1,400 per pipe, or about $185 a ton, while the market rate at that time was climbing to more than twice that figure. Although the fact was that the pipe would be stored in extremely harsh environments for more than four years, there were never any significant problems found with the pipe. TAPS also committed $30 million for the purchase of the first of several enormous pumps that would push the oil through the pipeline system, and which would sit idly by for several years.

Edgar Lynn (Tiny) Von Rosenberg

Von Rosenberg was born in Temple, TX in 1928 and graduated from Temple High School at the age of sixteen. He enrolled at Texas A & M and received his degree in mechanical engineering in 1948 when he was still only nineteen years old. He went to work for Reed Rollerbit in Houston out of college and stayed there for the next five years. During that time he joined the ASME (American Society of Mechanical Engineers) and became a prominent member and contributor of this society for the rest of his life.

In 1953 Von Rosenberg joined the American Iron & Machine Works in Oklahoma City, OK as a mechanical engineer, where he began to develop an interest and a great amount of expertise in metallurgy. Over the course of his entire career his expertise in metallurgy, and particularly in strength of materials and welding practices, became so prominent that he was often called upon for his expert advice and opinion on company based projects in the United States as well as around the world.

In 1964 Von Rosenberg left Oklahoma City and returned to Texas, joining Exxon (still called Esso at that time) in Houston as a combination mechanical engineer/metallurgist. He was initially assigned to determine the cause of any welding failure anywhere in the company, and then became the primary troubleshooter for nearly any type of Esso Company field failures around the world. He was also responsible for providing the specifications for any new pipelines with Exxon's responsibility. Over the course of the next five years he consulted with Exxon personnel not only on oil and gas pipelines, but also on oil line and oilfield failures, oil platforms, storage tanks, flange connections, fittings and valves. When the Trans-Alaskan Pipeline Project began to develop, he was Exxon's premier design engineer for the project, although he probably preferred a warmer climate.

Von Rosenberg stayed with TAPS (later known as Alyeska) throughout the project, maintaining some involvement in virtually every aspect of the design, through construction and startup. His knowledge of welding practices in arctic conditions and underwater drilling practices were instrumental in the ultimate success of the entire oil pipeline and support facilities. Von Rosenberg was a lifelong member of the API (American Petroleum Institute), and served as chairman of numerous committees. As a result he was often called upon by officials of other companies to render advice and recommendations for numerous and varied issues

Following his thirty year retirement from Exxon, Von Rosenberg formed his own very successful materials and welding consulting firm. During his time with Exxon and as a metallurgical and welding consultant, Von Rosenberg filed as many as nine patents with the U. S. Patent Office, including many of the welding practices that were used during the Trans-Alaskan Pipeline construction and are still being used today. There will be more about the involvement on this project by "Tiny" Von Rosenberg and the Task Force later in this course.

Transporting Pipe to the Arctic

Most of the American and Japanese ships carrying the pipe from Japan brought the pipe to the port at Valdez, the northernmost ice-free port in North America, where it was off loaded and carried two-high by trucks to a storage area. There at Valdez it was stored up to five-high with enough pipe stored to reach north to Fairbanks, the nearest city along the pipeline route. Fairbanks was more than three hundred and fifty miles north of Valdez and over three hundred miles south of Prudhoe Bay. The Alaska Railroad transported pipe from Valdez to Fairbanks for storage until needed for the central portion of the Alaska Pipeline. Although there were several sub-contractors who were given responsibility for constructing the pipeline, the line was to be built in three sections: north from Valdez to Fairbanks, north from Fairbanks to the Brooks Range, and south from Prudhoe Bay to meet the construction at the Brooks Range.

Seward on the Kenai Peninsula also was a port used by the Japanese ships to export enough pipe to be laid across the tundra from Fairbanks to a location in the Brooks Range, where it would meet the pipeline being laid from the North Slope. The Alaska Railroad had the responsibility for transporting the pipe from the port at Seward to the storage area in Fairbanks. The delivery of the pipe to Valdez and even to Fairbanks was somewhat routine by Alaskan standards, but transporting some 167 miles of pipe from Japan to the North Slope was going to be anything but routine. The number of pipe required to make this journey, since each pipe averaged about fifty-eight feet in length, would be a total of more than fifteen thousand lengths.

Each pipe section weighed between seven and a half and eight tons and presented one of the biggest challenges of the entire project: how could TAPS deliver that quantity of pipe across the Arctic Ocean to the North Slope of Alaska? The problem was resolved by the Trans-Alaska Pipeline maritime engineers, who determined that a sealift by Alaska Barge and Transport, Inc. barges would be the safest and least expensive method to deliver the lengths of pipe that would be needed. Puget Sound Tug and Barge Division began the barge program less than one year before the pipe would be delivered to the North Slope. PAC, a Pacific Inland Transportation Company, had been contracted by TAPS to transport the 48-inch pipe from the pipe mills in Japan to the state of Alaska..

The surveyors and engineers had calculated that 167 miles of pipe would be required to be installed from the North Slope of Alaska to a joining point in the Brooks Range. A total of fourteen barges were constructed, each with an area of more than fifty thousand square feet and fitted with temporary pipe supports that measured thirty-five feet high.

Two oceangoing tugboats were dispatched to Japan and Hong Kong where four of the special barges were being built, each of which would tow two of the barges directly to Prudhoe Bay. The tugboats then towed the four barges to the Wakayama Works and waited while the barges would be loaded with pipe from the mill. While the Japanese were skeptical that the four barges, each carrying more than ten thousand tons of pipe, could cross the Pacific Ocean and reach Prudhoe Bay, TAPS was very confident that the barge company knew what it was doing and that the barge system would be successful.

In addition to four of the barges having been built in shipyards in Japan and Hong Kong, another ten were built on the west coast of the United States. Much of the pipe was shipped to the seaport in Tacoma, Washington, where each of ten barges was loaded with between two and three shiploads of pipe from Japan. Simultaneously the two barges built in Japan and the two barges built in Hong Kong were loaded with pipe from the mill at Wakayama.

The ten barges began loading pipe in Tacoma, WA in February 1970, each barge holding two to three shiploads of pipe. Special care was taken to avoid any damage to the seam welds or the beveled ends of the pipe during the transfer of each pipe from ship to barge. When the four barges coming from the Wakayama Mill in Japan and the ten barges in Tacoma were fully loaded and ready, the ocean voyages began. The two tugboats now in Japan towed each pair of the two barges in tandem from the Wakayama Mill, the four barges holding a total of about fifty-four miles of pipe, to Alaska's Prudhoe Bay.

From Tacoma the tugboats, with over one hundred miles of pipe on board the barges, timed their movement to sail for Prudhoe Bay, more than three thousand miles away and well within the Arctic Circle. The shipments from Wakayama Works and from the Port of Tacoma rendezvoused at a point in the Bering Sea near Nome, Alaska. Included with the fourteen barges loaded with pipe were an additional twenty-six barges which were loaded with a total of 67,000 tons of general cargo. The fleet of twenty tugs and forty barges first encountered Ice floe near Pt. Barrow about 150 miles from Prudhoe Bay. Their idea was to arrive a week early and move through the Arctic Ocean as soon as the ice floe opened, which was usually about 02 August. However, a reconnaissance plane, which was monitoring the ice floe patterns, reported that there didn't appear to be any openings in the ice. The fleet of tugboats and barges had only forty days to move to Prudhoe Bay and unload the pipe and cargo and return to Pt. Barrow before the long winter freeze of the Arctic Ocean would set in.

After several days of not finding any opening, one tug carrying pipe from Japan was left at anchor at Pt. Barrow, while the other tug equipped with special gear and larger engines carefully towed two of the barges through the hazardous ice conditions the remaining ninety miles to Prudhoe Bay. The powerful tug boat then went back to Pt. Barrow and towed the other two barges through the ice floe to Prudhoe Bay. After several harrowing hours of careful travel through the icy waters, the ice floe finally broke up and, with daylight available all twenty-four hours of the day in the Arctic Ocean, the rest of the fleet quickly proceeded on to Prudhoe Bay.

However, when the barges began to arrive at Prudhoe Bay, they were faced with another serious challenge. Because the beach was so shallow, with a depth usually of only about four feet at high tide, the barges had to anchor nearly nine miles from shore. Realizing that the length of thawing time in the Arctic Ocean was only about forty days per year, the crews had to develop a spontaneous plan to circumvent the shallow beach, and would have to work around the clock to bring the thousands of pipe safely to shore and to return the ocean-going barges and tugboats back to ports.

A special dock was then built by sinking eight barges upside down and end-to-end to create a dock out into the ocean about one quarter mile long. Two shallow-bottom barges, each equipped with a 150 foot boom crane, began the process of transferring the pipe from the ocean going barges to lighter barges with drafts of three feet. Once the lighter barges were towed to the temporary dock, two more shallow-bottom barges with boom cranes were waiting to unload them. At the dock trucks with long flatbed trailers were in line to haul the pipe three miles inland. There the pipe, totaling more than fifteen thousand lengths, were offloaded onto a previously prepared gravel storage pad and were ready for installation. Nevertheless, through all of this handling of the pipe, special care was given to protecting the seam welds and preventing any damage to the pipe. Fortuitously, the Arctic Ocean was a few days late in freezing over that year, and all of the vessels were able to be safely returned to their ports.

Although all of the necessary pipe for the northernmost section of the pipeline was now on the ground at Prudhoe Bay by August of 1970, the Japanese continued to ship the balance of the pipe order to the two other key storage areas in Alaska through September. In early October of 1970 the TAPS Task Force traveled to Alaska to inspect the condition of the pipe as it sat in storage. Under the harsh Alaskan climate the outside surfaces of the pipe were moderately rusting, which was creating a coating surface for the pipe that was considered beneficial. However, the inside surface of the pipe was flaking, a situation that would cause problems later unless dealt with. Furthermore, the joint protectors were allowing moisture to be trapped inside the pipe to further exacerbate the problem. Lastly there was sufficient damage to enough of the beveled pipe ends, in spite of all the precautions taken during shipping and handling, to warrant the potential need for field beveling machining prior to welding the joints of pipe together.

B. Preliminary Engineering and Design

1. Surveying Challenges

At the same time that the executives of the three companies filed their plan with the U. S. Department of the Interior, they requested a permit to begin geological and engineering studies for the proposed oil pipeline route from Prudhoe Bay to Valdez. The permit was granted by the Interior Department based on the group's preliminary plan for running the pipeline down across the eastern side of Alaska. The surveyors and engineers began their preliminary surveying and geological work in the early summer of 1969, followed by a more intense and comprehensive survey in the spring of 1970.

The civil engineers and surveying crews reviewed aerial photographs and took hundreds of core samples, proposing several routes before settling on the most workable routing. The work was difficult, and animal dangers required that many in the survey crews were armed. Additionally they had to cope with dense foliage and trees that were in the route and had to be cut away. The final proposed pipeline routing across Alaska by TAPS passed through at least two major mountain ranges and several mountain passes, including the very ominous Brooks Range and Atigun Pass as well as the Alaska Range and Isabel Pass in the northern part of Alaska. There the slopes were so severe that normal footing and heavy machinery movement was treacherous and nearly impossible.

The route also passed through the Yukon Territory, which was halfway between Fairbanks and Valdez, and through Thompson Pass just north of Valdez. Thompson Pass is a 2,800 foot high gap in the Chugach Mountains, and has recorded snowfalls of over 62 inches in one day and 550 inches in one year (1955). In addition the engineers and surveyors had to deal with crossing hundreds of streams and rivers, and crossing over Denali Fault, a major intercontinental fault that extended from British Columbia to the center of the state of Alaska. The pipeline route that was ultimately chosen and approved crossed over more than 500 streams and rivers, all of which required special design considerations.

2. Forming of Alyeska

The Big Three original oil companies, an unincorporated joint venture that had been formed in 1968, still were without construction permits with which to proceed in the summer of 1970. TAPS had formally applied to the U. S. Department of the Interior for a permit to build the oil pipeline from Prudhoe Bay to Valdez. Requesting a 100-foot wide right-of-way, the initial plan was to build the entire pipeline underground. They also had requested a second right-of-way to build a construction and maintenance highway that would parallel the oil pipeline. Recognizing the enormous environmental and ecological difficulties associated with the planning and construction of an eight hundred mile-long oil pipeline through the heart of Alaska, they solicited support from other pipeline service companies. In the late summer of 1970 four additional oil exploration and oil service companies combined with the three original companies to form a corporation called the Alyeska Pipeline Service Company. The new corporation was comprised of British Petroleum and its new subsidiary Arco (47%) and Exxon Mobil (20.5%), as well as ConocoPhillips (28%), Koch Alaska, Unocal, and Phillips Pipeline Services.

From as early as August of 1969 first TAPS and then the newly incorporated Alyeska Company anticipated that construction approval of the project was just a few weeks away. Nearly four years before the Alaskan pipeline was officially approved by the U. S. government, Alyeska had placed comprehensive cost-plus contracts to supply the necessary project management, engineering services, procurement services, and construction management with two major firms in the United States. Bechtel Corporation, with much experience in the construction of pipelines in Saudi-Arabia as well as the Yukon in Alaska, was awarded the contract to supervise the pipeline construction in its entirety. Probably the largest engineering and construction company in the U. S. at that time, the San Francisco-based firm had a proven track record with mega-projects, such as having built more than five hundred warships for the U. S. in World War II, in addition to becoming a leading contractor for the nation's nuclear power plants.

Fluor Alaska, Inc., a division of Fluor Corporation originally based in Irving, Texas with its corporate headquarters eventually being moved to Orange County, California, was awarded the contract by Alyeska to provide the pump stations as well as the port terminal at Valdez, Alaska. Fluor, which was listed on the New York Stock Exchange, had also diversified into oil and gas operations with design and construction of oil pipelines, refineries, and petrochemical plants.

The new companies had come aboard as both advisory and investment partners since the oil discovery in 1968. In spite of their minimal economic support, they were also brought into the corporation as partners who would hopefully be able to exert political influence on Congress as well as other federal agencies in order to overcome the growing opposition to the oil pipeline construction from many sources. The new companies additionally had developed strong relationships over the years with pipeline subcontractors and union shop welders, all of whom would prove vital to Alyeska's construction efforts whenever final permits were approved.

The newly reorganized and newly incorporated consortium of companies was officially named the Alyeska Pipeline Service Company, a name derived from an Aleut word meaning "mainland". Edward L. Patton, a former Humble Oil (Exxon) manager was named Chief Executive Officer of the new company. He and the representatives of the new company began to lobby strongly for a resolution to the Alaskan Native claims dispute involving the pipeline right-of-way. In April of 1970 Judge George L. Hart of the U. S. District Court in Washington, DC had ordered the Department of the Interior to not issue any construction permits for the pipeline that crossed over land that was part of the claims. A few weeks later Judge Hart heard arguments from conservation groups that the new project violated both the Mineral Leasing Act as well as the National Environmental Policy Act. Judge Hart then issued the injunction which prevented the Interior Department from issuing any construction permits.

Even without being able to initiate any field construction, much engineering activity was being performed behind the scenes, primarily by Von Rosenberg and Loncaric, members of the original TAPS Task Force who were now being absorbed into the Alyeska Task Group. One of the early research areas by the Task Group which was fundamental to the success of the project was the ability of ARCO to extract oil from the North Slope in order to get it to the first pump station at the pipeline. All of the wells that would have to be drilled were either under ice-covered ground or under ice-covered water. The quality of the drill pipe and casing were of concern because many of the wells would be drilled in the Arctic Ocean, some at a depth of just a few feet. However, other wells would be drilled at a water and ice depth of more than 600 feet. The real problem was not the temperature of the water and the ice, but rather the atmospheric temperature in Prudhoe Bay that would reach in excess of -70°F at certain times.

Even before Alyeska officially took over the pipeline project, the TAPS Task Force was working with ARCO to develop materials that could withstand temperatures of -80°F. This included everything from the platforms and rigs down to the lug wrenches and pipe supports. Fortunately new metal materials had been developed during World War II, and new processes were being invented and tested throughout the Fifties and Sixties. Oil and natural gas discoveries were occurring in remote geographical locations and climates, and oil companies and drillers were being forced to go deeper and deeper below the surface in order to avoid a dry well.

The fact that some metal products would become harder if heated and quickly doused with water had been known for centuries. But now many steel companies and foundries, primarily in the United States, had charged their research departments with ways to market stronger, tougher products. The modern form of quenched and tempered iron and steel products really had its rise in the Sixties, mainly in the oil country tubular goods (OCTG) industries. While this course is not meant to be a primer on the quench and temper process, a brief summary will allow you to understand how the Alaska Pipeline benefitted from its timely development.

Q & T (quench & temper) product must contain a certain amount of ferrite and carbon, meaning that improvements for both the basic steel industries and the iron and steel foundries could result. The first step in the process is the heating of the metal at an austenitizing temperature of about 1650°F, which is nothing more than an annealing or normalizing process that would alter the grain structure of the metal to a more consistent alignment. Some of the earlier methods for heating the product were either through a series of induction coils or by passing the product through a gas-fired furnace, and either method proved to be acceptable.

However, the quenching of the product is the second and most critical step in the overall quench and temper process. The heated metal is then passed through a quench area, usually a circular ring of water spray at a certain temperature and pressure, which should result in changing the metallurgical properties from a pearlite structure to a martensitic structure. The technology associated with the type of quench utilized would often determine the quality of the end product that was produced. A product heated at an austenitizing temperature creates a heat film over itself which is called a "vapor barrier" and will repel vertical water flow. This vapor barrier must be quickly penetrated in order to "shock" the product and to substantially raise its hardness level, and the most efficient way to do this is to train the jet water spray onto the product at an optimum angle. This process can be likened to a lumberjack trying to fell a large tree with an axe. He can swing that axe horizontally at the tree and, even though he encircles the tree and uses great force, few chips will fall and progress will be very slow. Conversely, by swinging the axe at a particular angle and encircling the tree, he will form a "vee" in the tree trunk and is more quickly able to fell the tree.

The quench process following continuous induction heating such as occurs when austenitizing a string of piping or tubing usually does not permit proper angular penetration due to the likelihood that there will be an infiltration of quench water to the inside diameter of the pipe. This usually results because there is a gap between the tail end of the lead pipe and the lead end of the following pipe caused by even the slightest bowing or other irregularities of each pipe. Thus this internal cooling effect, especially on higher grade and higher alloy pipe and tubing that occurs before the outside diameter has been properly quenched, causes what is commonly referred as "quench cracks." This condition will not only cause lower yields for the producer of the pipe but could result in massive fatigue failure in the field if undetected in the inspection process. The modern way to combat this problem is to have a forward impinging quench on the lead end of the pipe as it is being conveyed forward through the quench area, switching to a reverse direction impinging quench on the tail end of the pipe.

While proper quenching does raise the hardness of the metal product substantially, it also creates a brittleness that can't be tolerated. Therefore, the third and final step in the Q & T process is to temper the product, or to indirectly subject it to a uniform soaking temperature of between 1100°F and 1150°F. This tempering process, which is usually performed in recirculation types of furnaces, will further increase the strength of the product and will vastly improve its ductility as well. This process cannot be done effectively by direct-fired furnaces simply because the burners utilized in these types of furnaces do not have the turndown ratio capabilities to achieve the lower temperatures required for uniform tempering.

There was an additional benefit to ARCO using Q & T drill pipe and tubing and casing on the North Slope which the TAPS Task Force had not envisioned initially - those products held up much better under the extremely cold Arctic environment. The TAPS Task Force, which was integrated into the Alyeska Task Group gradually in 1971 and 1972, had already commissioned the Battelle Institute of Columbus, Ohio to perform tests on virtually every product that was being planned for the Alaskan Pipeline. While the newly formed Alyeska Metallurgical Task Group maintained responsibility for the non-destructive testing (x-rays, ultrasonics, and fluoroscopy), Battelle provided the critical data related to destructive testing (cryogenics, tensile tests, Charpy v-notch and impact tests, etc.) for items such as valves, flanges, pipe and tubing, and fittings.

C. Environmental and Political Obstacles

1. Court Battles

Wally Hickel, the previously elected governor of Alaska, had already been named Secretary of the Department of the Interior by newly elected United States President Richard Nixon on 29 January 1969, so there was much enthusiasm that project approval would occur quickly. The Alyeska Task Group provided Bechtel with very concise welding specifications for the joining of the pipe in all weather conditions, and supported them with testing requirements for the individual welders as well as numerous non-destructive testing procedures. The Task Group also met frequently with Fluor's organization in Los Angeles and Anaheim to provide them with tank welding and testing specifications as well as specifications for tubing, flanges, valves, fittings, and other materials and instrumentation associated with the pump stations and the terminal at Valdez. As chairman of the American Welding Society (AWS), Von Rosenberg had developed and had tested cold climate welding practices that would need to be followed by all of Alyeska's many pipeline sub-contractors.

When William Egan won reelection as governor of Alaska and began his term on 07 December 1970, Alyeska's personnel were confident that project approval was imminent. Governor Egan was a strong proponent of advancing Alaska's economy and, although he recognized and understood the delicacy and complexity of its environment, realized that the State of Alaska and its natives as well as the influx of thousands of new citizens would benefit greatly from the 800-mile long oil pipeline. Egan had been governor of Alaska when it was admitted to the United States on 03 January 1955, so he knew the state better than most.

.Former governor and now Secretary of the Interior Hickel also proved to be a strong supporter of the pipeline and showed an interest in much of the planning of Alyeska, making only a few requests on issues that would require long-term solutions. Nevertheless, following approval by the Department of the Interior for the service road in 1970 and the issuing of contracts for the construction of the service road, a group representing Native Alaskans almost immediately asked for an injunction to prevent the Interior Department from issuing the necessary construction permits. Their objection was due to the fact that the pipeline would run through their villages, for which they had signed waivers, but not one of the Native construction firms was being considered for any of the road construction.

Hickel, who was interested in pursuing solutions to any problems or issues that would affect the construction of the pipeline, was ordered by DC District Judge Roy Hart to not issue any permits until the suit that claimed the pipeline crossed over native lands that had not signed a waiver was resolved. Shortly thereafter the judge heard arguments from environmental groups that the TAPS project violated certain Mineral Leasing Acts as well as the National Environmental Policy Act, following which Judge Hart issued a permanent injunction against further construction of the project. This decision did not sit well with Alyeska nor Hickel, and he joined the Alyeska representatives to seek a monetary solution that would bring a positive result to the native Alaskan population.

Somewhat unfortunately for Alyeska and the State of Alaska, his tenure as Secretary of the Interior Department came to an abrupt end. Hickel had become an opponent of the war in Viet Nam, and had clashed with many members of Congress. In addition he was not treated kindly by the New York Times, primarily because he had refused to embrace their ideology regarding the oil pipeline's impact on the environment in Alaska, although he did share their disenchantment with the war in Viet Nam.

When a student protest erupted at Kent State University in May of 1970 following President Nixon's announcement that the U. S. planned to bomb Cambodia, the Ohio National Guard was called to duty. During the course of trying to quell the protest, four students were killed and nine others were seriously injured.

Hickel couldn't remain silent, extending his personal objection for the war to President Nixon as well as to any and all who supported the war. He wrote a letter to Nixon, which the Times and others were eager to publish, citing the thousands of war casualties and the many hundreds of thousands of young people throughout the United States who were opposed to the war in Viet Nam and were being disenfranchised by Nixon. He was especially critical of Nixon's failure to even consider the feelings and beliefs of the younger generation. Within a few weeks following the publishing of that letter in newspapers across the country, Nixon fired Hickel and two of his Undersecretaries, and the Alaskan Pipeline lost a key supporter and remained on hold.

Primary Environmental Obstacle

One of the main issues with the Interior Department had been that the plans called for a majority of the pipeline to be buried. The Interior Department responded by sending a team from the Naval Arctic Research Laboratory at Barrow, Alaska to analyze the proposed route and construction plan. Headed by geologist Max Brewer, he and his team concluded that this practice would prove unfeasible due to the abundance of permafrost through which the pipeline would pass. Furthermore, Brewer presented evidence that burying the pipeline would cause the support of the pipeline, carrying hot oil, to fail as the underlying material turned to mud. The Interior Department put a temporary hold on the project until this issue was resolved by the engineers, and members of the Task Group were requested to study the issues and develop a plan.

Although NARL had used some predictable oil temperatures that were somewhat higher than the actual oil temperatures that would arrive at the first pump station, their assumptions proved to be generally valid. Only a small amount of the pipeline could safely be buried, and even that small amount would have to be insulated in such a manner that neither the pipeline nor the permafrost would be affected. The TAPS Task Force and Bechtel engineers formed a pipeline insulation committee which specified the type of covering and bed material for any part of the pipeline that would be buried in the ground or under a riverbed. Once this issue was resolved, the Interior Department lifted the hold on the temporary ban and TAPS began to solicit contractors for the construction of the pipeline roadway.

Max Brewer and Permafrost

Max Brewer was born and in Alberta, Canada in 1924, but as a teenager he and his family moved to Spokane, Washington. After becoming an American citizen, he joined the U. S. Army Air Force and served in World War II before returning to civilian life and receiving a Bachelor of Science Degree from the University of Washington in geology. Following graduation Max first visited Alaska in 1948, eventually moving to Barrow, one of the northernmost cities in Alaska, where he performed geothermal studies for the U. S. Geological Survey organization. In 1956 at the age of thirty-two he became the youngest director of the Naval Arctic Research Laboratory, a position which he held for the next fifteen years.

Max utilized his experience in the USAAF to pioneer light aircraft travel throughout Alaska as well as the Arctic Region, and was credited with establishing more than a half dozen ice island research centers during his time with the NARL. Max was a pragmatic environmentalist who had similar sentiments as Governor Egan and realized that, although economic progress would be made to the benefit of the natives and incoming population of Alaska, he would have to do everything in his power to protect the animals, the land and the natural habitat of Alaska.

Max's knowledge of the Arctic Region and his insights proved to be invaluable to the Department of the Interior as well as to the oil companies and the pipeline engineers. His most famous declaration was his response to the initial plan by the oil companies to bury the oil pipeline, and what the line carrying hot oil would do to the permafrost, a term defined as the level of soil, rocks, silt and glacier residue that would remain in a frozen state for two or more years. Max was able to alert the oil companies to the hazards involved with a sinking and unstable pipeline itself which could result in catastrophic consequences. His innovations and recommendations extended well beyond the design and construction of the pipeline to include the service roads, the pump stations, and other necessary temporary and permanent buildings.

One of Max Brewer's greatest honors was being appointed by Governor Egan as the State of Alaska's first Commissioner of Environmental Conservation in 1971, a role in which he helped to ease the tensions between hardcore environmentalists and energy-seeking industrialists. Max's character as well as his ideas and ability to reach meaningful compromise helped to pave the way for economic progress in Alaska. Later he rejoined the U. S. Geological Survey, first as chief scientist and environmental engineer, and then as chief of operations. Max Brewer received many awards for his achievements for his work on behalf of the State of Alaska, including an honorary doctorate in science from the University of Alaska, the U. S. Department of the Interior's highest Distinguished Service Award, and the U. S. Navy's highest civilian honor, a Distinguished Public Service Award.

Alyeska Continues to Plan

Although the project had been shut down by District Judge Hart, the involved oil companies continued to make plans for the oil pipeline (as well as the natural gas pipeline, albeit surreptitiously). Over the next three years they used their influence with the U. S. Congress to help move the project through the courts. Alyeska representatives lobbied Congress for approval to lift the injunction, and the issue of compensation to the Alaskan Natives was resolved in October of 1971 when President Nixon signed the Alaskan Native Claims Settlement Act. Under this act Native Alaskans would waive all of their land claims, and it would offer Native Alaskan villages and regional settlements nearly $1 billion plus almost 150 million acres in federal land, none of which would interfere with the routing of the pipeline.

Further objections were raised to the pipeline's construction by both the environmentalists as well as Congress. The claim that herds of caribou would be restricted in their migration were laid to rest when Alyeska officials were able to counter that contention by simply noting that caribou were able to jump over a similar sized 90 mile long water line that had been constructed in central Alaska nearly fifty years earlier. Other environmental objections included the long lasting effects that the pipeline would have on the Alaskan environment and the fear by the fishing industry of oil tanker leaks south of Valdez, which actually did occur more than a decade later.

All of these concerns were highlighted and somewhat mitigated by a large, nine volume environmental impact statement that was released in March of 1972. While the study proved to be neither a proponent nor an opponent of the pipeline construction, it was somewhat supportive of the pipeline. Then U. S. Secretary of the Interior Rogers Morton held forty-five days of hearings, and the environmentalists opposed nearly every positive aspect of the impact statement. Present at these meetings were members of the Alyeska Task Group, led by Von Rosenberg, who was both knowledgeable and credible.

The hearings were held in Washington, DC as well as in Anchorage, and the environmentalists were given full voice. However, after their objections were heard and listed in another large document, they failed to influence the judge, who lifted the injunction in August of 1972. Nevertheless, the same environmental groups claimed that the pipeline did not follow the strict guidelines of the Mineral Leasing Act, and a Court of Appeals in Washington, DC, partially reversed the District Judge's decision in October 1972. The U. S. Supreme Court failed to hear an appeal by Aleyska attorneys in April 1973, thus allowing the lower court decision to stand. Almost. three years after the last pipe had been delivered to Alaska, Alyeska still had no construction permits from the U. S. Department of the Interior.

2. Congressional and Presidential Approval

Following that rejection by the Supreme Court to hear the appeal, Alyeska representatives and oil company executives put a full court press on Congress to have them change the Mineral Leasing Act. This of course received strong opposition from the environmentalists, who were now looking for any arguments that might prevent the pipeline from being constructed. Various options were again being considered, including the rerouting of the pipeline through Canada. Meanwhile an amendment to the Mineral Leasing Act had barely passed in the Senate in August 1973. This bill allowed for a much larger right-of-way for the pipeline than had originally been permitted, thus further encouraging Alyeska officials and engineers that both an oil line and a natural gas line could be constructed after all. Without any hesitation, the bill was immediately signed into law by President Nixon.

Just two months later in mid-October of 1973 OPEC, the Arab-led Organization of Petroleum Exporting Countries, placed an oil embargo on the United States because of America's support for Israel during the Yom Kippur War. This surprise embargo was primarily initiated by Egypt, Syria, and Jordan as the result of their humiliating defeat by Israel in the six-day war in 1967 that had allowed Israel to take over the Sinai Peninsula and the Golan Heights. Russia sided with the Arab nations, which caused some great anxiety in the U. S., but a brokered agreement was arranged in late October of 1973, which eventually allowed Israel to maintain the Golan Heights while subsequently relinquishing the Sinai Peninsula back to Egypt. Following the restoration of the Sinai back to their nation, Egypt gradually moved away from the Soviet Union and, notwithstanding the short lived election of the Muslim Brotherhood in 2013, has arguably been the primary Arab nation at complete peace with Israel.

The Arab embargo had a disastrous and debilitating effect on the American economy, inasmuch as more than one-third of the U. S. oil supply was being primarily imported from the Middle East. The price of gasoline, when it was available, shot up dramatically. Long lines of automobiles, station wagons, and pickup trucks (SUV's probably hadn't been invented yet) formed at the pumps of gas stations whenever American drivers received rumors that a gasoline tanker truck was due at a particular location. A form of semi-rationing took place, with vehicles having license plates ending with even numbers being allowed to buy gas on the even-numbered days of the month, while those ending in odd numbers could purchase gasoline on the odd-numbered days. President Nixon, who had been a proponent of TAPS and Alyeska even before the embargo, as well as the American public, pushed Congress to act.

The Trans-Alaska Pipeline Authorization Act was drafted, pushed through committees, passed by the House and the Senate, and signed into law by President Nixon on 12 November 1973, just four weeks after the oil embargo began. A federal right-of-way permit for both the pipeline and the service highway was granted in early January 1974, the oil companies signed onto the agreement within a week or two, and work on the pipeline officially was able to begin on 23 January 1974

After nearly four years of dealing with legal and environmental issues, Alyeska was now preparing to embark on the largest privately funded project in the history of the United States. They had estimated that approximately 500 million barrels of crude oil would have to be delivered to the United States before the partners would begin to realize an after-tax profit at the projected price of oil once the pipeline were in operation. Fortunately for Aleyska and the state of Alaska and the United States, they were able to achieve that milestone in slightly less than three years from the time that the first oil flowed through the pipeline.

3. Pipeline Challenges

The route that had been planned by the survey crews and the geologists was a fairly direct route, but it was hardly a straight line. The route began at the collection point in Prudhoe Bay, climbed over the Brooks Range and through Atigun Pass, went through miles of heavy foliage and rugged terrain, and traveled through three miles of Keystone Canyon with its nearly perpendicular walls before arriving at the Valdez Marine Terminal. Furthermore the pipeline had to cross over the Denali Fault as well as to cross under or span all of the more than five hundred rivers and major and minor streams.

Some of the major factors that the Alyeska Task Group and Bechtel had to take into consideration included:

1. No pipeline could be buried where the heat of the oil flowing would cause the permafrost to thaw. Note: The heat of the oil coming out of the wells at Prudhoe Bay was about 130°F, while the oil entering the first pump station would still be greater than 120°F.

2, The pipeline had to be either low enough in some areas to allow the Caribou to jump over it, or high enough in other areas to allow the Caribou to pass beneath it.

3. The pipeline had to allow for expansion due to the heat of the oil.

4. Streams and some smaller rivers could be excavated to allow for burial of the pipeline, but a method of insulation and anchoring was required to provide protection for any pipe that was buried.

5. Special consideration had to be given to where the pipeline crossed over the Denali Fault, a major intra-continental slip extending from just north of British Columbia across the entire southern portion of Alaska, which had seen numerous earthquakes and displacements in the past.

There were a handful of other regulations and requirements that had to be considered by the engineers and designers of the pipeline, but the above list included the most significant ones.

<u>Solution 1 - Buried Pipeline:</u> This issue proved to be paradoxical in that ecological objections required subterranean crossings of the pipeline in order to allow caribou and other wildlife to cross over. Engineers developed a system which actually refrigerated the ground around the pipeline with a chilled brine. The refrigerated sections of pipeline were then placed in Styrofoam-lined trenches and covered with gravel to further improve their insulation value. Less than five miles of the pipeline was built in this manner, but in other locations where permafrost was not a factor, the pipeline could be directly buried without any special refrigeration system.

<u>Solution 2 - Elevation Pipeline</u>: More than half of the 800 mile pipeline was built above the permafrost, which required that the heat generated by the oil in the pipeline had to be dissipated. Each of the tuning-fork shaped stanchions for the elevated sections of the pipeline contained sealed tubes of ammonia. The ammonia absorbed the heat and rose to a pair of fin-type radiators atop each support. The ammonia was then cooled by the outside air, condensed, and precipitated to the bottom of the tube as part of a continuous cooling cycle.

<u>Solution 3 - Expansion Allowance</u>: A straight line from the Prudhoe Oilfields south to Valdez was less than six hundred and fifty miles. However, the pipeline was designed to be laid in an s-shape in each of the different sections, due in part to the expansion of the steel pipe as well as to the irregular terrain. Rarely did any straight line portion of the pipeline exceed two hundred and fifty feet, and any camber and bow resulting from the pipe manufacturing process were used to the advantage of the engineers in the assembly of the pipeline.

<u>Solution 4 - Crossing Streams and Rivers</u>: Each section of the pipeline had to cross numerous streams and small rivers. However, excavation or dredging of any riverbeds was impermissible due to environmental concerns, so the engineers had two choices. Where the pipeline crossed the streams and smaller rivers, they had the pipeline encased in a concrete jacket to weigh it down, which prevented it from rising (oil is lighter than water) as the streams rose. In a few instances the engineers designed pipe bridges, such as the one that also carries the Dalton Highway over the Yukon River, as well as the long suspension bridge that carries the pipeline over the Tanana River about one hundred miles south of the Yukon River. To protect against

pipeline corrosion in these wet environments, the engineers designed a system of cathodic protection which utilized aluminum as the primary sacrificial anode.

Solution 5 - Denali Fault: Traversing the state of Alaska from east to west, the Denali Fault presented a significant challenge to the engineers. Because it was primarily in the southern region of Alaska, the large amounts of permafrost compounded their problems and necessitated an elevated pipeline design. This required the pipeline to be insulated for more than one thousand feet, and to then be constructed in an atypical s-shape and placed on Teflon coated slider supports in order to accommodate future movements. Note: An earthquake occurred in 2002 which proved the merits of the system, although some of the sliders were damaged and had to be replaced.

Pump Stations Challenges

Beginning at the North Slope with Pump Station No.1, twelve pump stations had initially been planned by the Alyeska Task Group during their numerous meetings between the end of 1970 and November of 1973. Only eleven pump stations were initially deemed necessary, with the first four pushing oil through the pipeline and over the Brooks Mountain Range. The other seven pump stations were to be located south of the Arctic Circle, three above Fairbanks and four between Fairbanks and Valdez.

The massive pumps that were responsible for moving the oil through the forty-eight inch pipeline were to be powered by either natural gas or liquid-fueled turbines. The huge enclosures sat atop large gravel beds to prevent contamination in the event of an oil spill. Each element in the pump station had to be tested to withstand numerous extreme cold conditions, and all components had been heat treated, including the associated piping, flanges, fittings, and control valves. Battelle Institute of Columbus, Ohio, a no-profit research facility that focused primarily on metals and material sciences during the 1970's, was a regular stop for the Alyeska Task Group. Any material or product that was chosen for the project, whether it be tubing or valves or any necessary components of the pipeline project, was routinely tested by Battelle, often to failure. When the project was approved in January of 1974, Alyeska had compiled a comprehensive list of equipment and equipment suppliers that could satisfy their most stringent requirements.

Valdez Terminal Challenges

Alyeska's plans required that a marine terminal be constructed on an approximately 1,000 acre site at the south end of the oil pipeline in Prince William Sound. The terminal would be located in an extremely environmentally sensitive area which was at the eastern end of the Bay of Alaska. The port of Valdez was at the very tip of an irregular mountain range, which presented a specific site and location problem for Fluor. In addition the bedrock in the area was nearly sixty feet below the ground level, thus necessitating the removal of more than 15 million cubic yards of overburden in order to provide a stable base.

The terminal was initially designed to have four oil tanker berths, with an allowance for a fifth, but a total of six were eventually constructed. Two were used for filling the tankers, while the other four berths were to accommodate the tankers moored and in waiting. At the time the Valdez Terminal had the largest floating berth in the world, which was also the largest single pre-constructed component of the project. Eighteen storage tanks were built and installed, and the tanks were 250 feet in diameter and approximately 64 feet high. Each tank had a capacity of more than 8 million gallons of oil, and the system was designed to have the capacity to hold the oil in the entire 800 miles of pipeline, should emptying of the pipeline ever become necessary.

There were three power plants at the Valdez Terminal, and each plant generated 12.5 megawatts of electricity. Furthermore, the Pipeline Authorization Act required that a filtration system be provided for the ballast water of oil tankers. This was constructed to prevent any oil contamination from being released into the Sound, and was a primary concern of the local area fishermen.

D. Construction

1. Constructing the Dalton Highway

Although all the legal challenges had been met by February of 1974, brutally cold weather and the lack of experienced workers prevented the actual construction work from beginning until April of 1974. In February, 1974 convoys of heavy equipment began to head north toward Prudhoe Bay, loaded on snow tractors and running over snow-covered and icy terrain. Traveling over the Yukon River on an ice bridge, they reached the several construction camps that had been built and lain dormant since 1970. At that time Alyeska awarded a contract for the design of the pipeline access road to Michael Baker Jr., Inc., a heavy construction and civil engineering company from Moon Township, PA. Baker had extensive road-building experience throughout North America and was contracted to design the pipeline service and maintenance road in less than three months..

Once the design of the service road, subsequently named the Dalton Highway, was completed, Alyeska selected four sub-contractors to perform the construction. Although construction did not begin until the end of April of 1974, the complete roadbed was laid down and leveled between the Yukon River and Prudhoe Bay within six months. More than a half dozen temporary airstrips were built along the route either near the existing construction camps or in proximity to the four proposed pump stations north of the Yukon, and a massive airlift was created to supply the hundreds of thousands of tons of gravel that was needed. In addition at least twenty small bridges had to be constructed over streams and ravines, so that the entire 167 miles of roadway was open to traffic by November of 1974.

More than three thousand workers were employed by the contractors and Alyeska during this construction. The road has since been paved in several sections, although much of it is still primitive and extremely steep in some places. It parallels the pipeline, reaching its highest altitude, similar to the oil pipeline itself, of nearly 4,800 feet above sea level at Atigun Pass. While the road terminates within a few miles of the Arctic Ocean, there are private roads owned by the oil companies that allow for commercial tours to the Arctic. Truck traffic was at its peak of more than 1,000 vehicles per day during the pipeline and pump station construction, but still averages about 200 vehicles per day.

2. Constructing the Yukon River Bridge

Passage over the Yukon River, which essentially divides the northeast section of Alaska from the southeast portion, proved to be another challenge. The bridge had to be built as an integral part of the Trans-Alaskan Pipeline in order to carry the pipeline as well as to connect the north and south routes of the Dalton Highway. Alyeska's Metallurgical Task Group, led by Von Rosenberg and Joe Willing of Exxon, another engineer from the Alyeska Task Group, first completed the Yukon Bridge specification as early as 26 October 1971. After a few modifications in the types of steel from A514 to A537 on the tension side of the beams, the official specification was presented to the State of Alaska highway Department on 07 March 1972.

The bridge was designed as a girder bridge, and the State of Alaska agreed to pay two-thirds of the cost, with Alyeska being responsible for the other one-third of the cost.. Because construction of the bridge was dependent on the final approval of the oil pipeline, the bridge was not anywhere near being completed before the winter of 1974-1975 arrived. This resulted in all winter traffic having the requirement to cross the river on another temporary ice bridge. As the bridge was still under construction in the spring and summer of 1975 and 1976, all traffic was required to be transported by ferry boats across the river during those two years of heavy activity.

The new bridge crossing the Yukon River was constructed by a joint venture of Manson-Osburg-Ghemm, headed by the Manson Construction Company of Seattle, and was nearly completed by the end of September of 1976. The Yukon River Bridge, which was nearly one-half mile long, had a width of only about thirty feet. The bridge had a two foot expansion allowance for climate changes between the summer and winter temperatures. The bridge roadway was a timber surface lying on a steel deck, which was supported by box girders to minimize torsion. A minor dispute had ensued back in September of 1975 over ownership of the bridge, and was essentially settled with the State of Alaska agreeing to take ownership of the bridge as well as the Dalton Highway, while Alyeska was given the right-of-way to utilize the bridge until the oil pipeline's ultimate completion in 1977. In 1982 the State of Alaska officially named the bridge in honor of Edward L. Patton, who was president of the Alyeska Pipeline Services Company during construction of the Pipeline.

3. Constructing the Pipeline

Pipeline Responsibilities

Supervision of the many sub-contractors who put together and laid the oil pipeline was the responsibility of Bechtel Corporation. The laying of the pipe was somewhat along geographical lines and was divided up among several sub-contractors. Going from the north end at Prudhoe Bay to the south end at the Valdez Terminal, the pipeline's responsibility for construction was defined in the following manner. The northernmost section covered about 210 miles and went from Prudhoe Bay to Coldfoot, an area about twenty-five miles north of the Arctic Circle, which included the Brooks Range and Atigun Pass. This section was under the supervision of Arctic Constructors, a joint venture among Brown and Root Incorporated, Ingram Corporation, Peter Kiewit and Sons, Williams Brothers Alaska, and the H. B. Zachry Company of San Antonio.

Section two of the pipeline was 143 miles long, extended from Coldfoot to just south of the Yukon Territory, and was contracted to Associated-Green. Associated-Green had been one of the main contractors for the construction of the Dalton Highway, and was later awarded a contract by Alyeska to provide environmental cleanup for the abandoned pipeline camps.. Section three covered 144 miles from near the Yukon Territory south to Delta Junction just north of Fairbanks, and this contract was awarded to R. B. Potashnick, Codell Construction, Oman Construction, and H. C. Price Companies.

Section four, which covered 149 miles from Delta Junction to Sourdough and included Isabel Pass, was contracted to a joint venture of Perini Corporation, Majestic Construction, Wiley Oilfield Hauling Ltd., and McKinney Drilling Company. The fifth section was one of the most complicated sections of the oil pipeline construction.. This section ran 153 miles from Sourdough south to Valdez and then across the Alaskan Sound to the location of the tanker berths at the Valdez Terminal. This contract was awarded to Morrison-Knudsen Company's River Construction Division.

Setting Up Pipeline Camp

In the four-year period that occurred while first TAPS and then Alyeska were struggling to achieve construction approval, between them they had already managed to set up a dozen pipeline construction camps. Although all of these camps were north of the Yukon Territory, Alyeska realized that several more construction camps would be needed. Because Fairbanks was the only city of any significance along the pipeline route, and only about 170 miles north of Valdez, seven more camps were built south of the Yukon, while one camp was built at each of the proposed twelve pump stations along the pipeline route.

The camps were modular structures that could each house between twenty-five and thirty workers, and were joined together horizontally to form wings, except at Valdez and the pump stations where they were stacked two-high. The camps at the pump stations housed about 250 workers and supervisors, the pipeline construction camps housed more than 500 workers and supervisors, while the camp at the Valdez Terminal housed more than thirty-five hundred workers and supervisors. at its peak

There was also a construction headquarters set up at Fort Wainwright outside of Fairbanks, where Alyeska's engineers and the management from Alyeska and the many construction companies would stay. The buildings and barracks were leased from the U. S. Army by Alyeska, and were converted into housing for its sub-contractors and their workers. In order to relieve some of the burden on the Fairbanks International Airport, Alyeska also had an agreement with the U. S. Army to use Fort Wainwright's airfield.

Welders and Workers

All welders as well as all equipment operators and other members of the labor force were required to belong to a union. Per a binding agreement between Alyeska and the Unions, hiring was based on union seniority and strikes were forbidden. In exchange for these restrictions the employees of the various companies were paid much higher than national average wages, were guaranteed a forty hour work week regardless of the weather, and were offered substantial fringe benefits for that time. Priority was given to hiring permanent Alaska residents and natives. However, because of the living and weather conditions, turnover was very high. During the peak construction years of 1975 and 1976 more than twenty-five thousand people, including about 8% women, were employed and upwards of seventy thousand personnel worked on some part of the pipeline construction.

The welders who performed the task of welding the pipeline proper were members of the Pipeliners Local 798 from Tulsa, Oklahoma, and were the highest paid of all the workers who were employed on the project. A second welders' union, The United Association of Journeymen of the U. S. and Canada, were responsible for all other welding, including the feeder pipelines, all pump stations, and the entire Valdez Marine Terminal. Each welder was put through a rigorous qualification test before being accepted. Any welder who failed the qualification test was placed in the back of the line and could not retake the test for a period of six months.

Operators and Teamsters

The men (and women) who operated the controls of the heavy equipment used on the project's construction were represented by the International Union of Operating Engineers. The equipment, none of which was enclosed or heated, included bull dozers, drilling rigs, large and small crawler cranes, and sidebooms, which was a crawler crane that could lay a section of pipe in a trench on either side of the machine. Allowing for frequent breaks because of the frigid weather and the requisite anti-freeze that was imbibed out of necessity to stay unfrozen, as many as half a dozen operators might be assigned to the same piece of equipment on any given day.

By far the largest union manpower on the entire pipeline project belonged to the Teamsters, who provided all transportation and literally controlled all supplies. The Teamsters, which had a workforce in excess of twenty thousand employees at the peak of the project's construction, ran the buses that carried the workers to and from the camps to the worksites and managed and controlled the supply warehouses at each site. Their control of tools and equipment led to many conflicts with both pipeline management and other crafts and unions. Although forbidden to strike, the Teamsters did shut down a major portion of the project in early 1975 following a string of accidents with pipe hauling trucks on a treacherous section of ragged road leading to the Dalton Highway. Teamster leader Jesse Carr stopped all truck traffic in the entire state of Alaska for four days of safety meetings, or until Alyeska and the State agreed to provide upgrades to the road.

Carr, who had moved to Alaska from Ontario in 1951 at the age of twenty-five as a truck driver, had become an activist in the Teamsters Union, and had led the amalgamation of five different unions in the state to one statewide union. He was named president of Teamsters Local 959 with an ultimate membership of more than 23,000 people. He became a political power in the State of Alaska as well as throughout the United States when Alaska became a state, and was named to the Board of Directors of the Bank of Alaska. Carr was later named vice-president of the International Teamsters Union only seven months before his untimely death in 1985.

Actual Pipeline Construction

Although the Trans-Alaskan Pipeline received official approval in late January of 1974, the first section of the pipeline was not laid until 27 March 1975. Several sections of pipe were welded together in a 1900 foot length, a trench was dug across the riverbed, and several sidebooms laid the pipe into the trench. Alyeska engineers had previously devised a plan whereby the pipe would be coated with a heavy layer of concrete as ballast (oil is lighter than water and engineers feared that the oil-filled pipeline would lift) and to protect the pipeline from heavy flooding waters in the spring and summer. Bulldozers then filled in the balance of any of the exposed trench with gravel to restore the riverbed to its original contour and grade.

Alyeska's engineering Task Group and Frank Moolin, Jr., the Alyeska Senior Project Manager, had originally planned to lay about 45% of the pipeline in 1975, about 50% of the pipeline in 1976, and the remaining pipeline in the spring of 1977.The procedure for laying the pipe was basic but hardly easy. First the route had to be examined again by the surveyors and engineers, then the pathway had to be cleared and a determination had to be made to dig a trench or to elevate the pipeline. Since the great majority of the pipeline was elevated, vertical support members fabricated by Consolidated Western in Commerce, California were set into drilled holes in the ground and sealed in place by gravel, dirt and water. The supports had 48 inch semicircular rests, each pair of supports was set in parallel, and they were welded together in pairs for added stability. In total there were an estimated 78,000 vertical supports to hold the pipeline above the permafrost for the above-ground sections of pipeline.

As was noted earlier, the amount of SAW pipe used for the project was 800 miles, even though the straight line route between Pump Station No. 1 and the Valdez Terminal is somewhat less than 640 miles according to the coordinates of the maps. The maximum grade of the pipeline is 145% at the aforementioned Thompson Pass in the Chugach Mountains. Forty-two thousand of the pipe sections, either forty footers or sixty footers in length, were welded together, using automatic welders which Alyeska's Task Group had first discovered in March of 1972 while working on a project in Holland. These welders were equipped with expandable plugs that provided a concentric joint, and these plugs were utilized throughout the project. In addition, more than sixty thousand girth welds were manually performed in the field to provide the continuous string of the 800-mile long pipeline.

Frank Moolin, Jr.

Moolin, who had worked on similar projects for Bechtel, was a contract employee of Alyeska apparently known for his strong work ethic and his hard driving style. He was dissatisfied with the lack of progress that had been made in laying the pipeline in 1975, primarily because the construction portion of the plan was not organized until mid-summer of that year. Moolin had established an extremely ambitious pipe laying schedule for 1976, despite the fact that most of the pipe that had been laid to that point was on flood plains and relatively flat terrain.

He had various methods for spurring progress, and pitted the five major sub-contractors against each other in a competitive manner in order to expedite the project. Moolin's efforts were successful in accelerating the pipeline construction schedule in 1976, a year in which nearly every Alyeska pipeline sub-contractor exceeded its pipe laying schedule. Moolin was named the construction industry's Man-of-the-Year for 1976 by the Engineering News Record. Moolin also made other news in 1976 by embarrassing the giant contractor Bechtel by arranging to have Bechtel's cost-plus fixed fee contract on the pipeline terminated. Moolin felt, whether completely justifiable or not, that Bechtel was overtly padding their management hours in order to take advantage of their cost-plus fixed fee contract that had been awarded to them six years prior by Alyeska.

Welding Controversy

When a welding controversy arose in 1976 as the result of several pipeline welds that had been done the previous year, the entire project came to a near-halt while the Alyeska Task Group led by "Tiny" Von Rosenberg reviewed sub-contractor procedures and evaluated specific x-rays. A Mr. Kelley, a former employee of Ketchbaw Industries, had filed suit against his former company with the claim that he had been laid off because he would not join in the conspiracy to falsify quality control x-rays of pipeline welds. The pipeline was unique in that respect because the Task Group had specified that all welds in the main pipeline had to be verified by x-ray, a very time-consuming process. Owing to that suit and the subsequent turmoil that erupted all the way to Washington, DC, Alyeska terminated Ketchbaw's contract and took charge of the investigation.

Amid the continuing lawsuit, a Ketchbaw manager was found dead of cyanide poisoning and x-rays of welds were apparently stolen. Alyeska's Task Group initiated a review of more than 30,000 pipeline welds that had been made in 1975. In February of 1976 the Alyeska Task Group met several times and issued a report to the Department of the Interior. In late June of 1976 Alyeska was then invited to provide testimony on their welding requirements and activities on the pipeline before Representative John Dingell, Michigan, Chairman of the House Energy and Commerce Committee. Since Dingell had graduated from Georgetown University with a BS degree in chemistry, Alyeska believed that his background would enable him to understand the welding requirements that were necessary and the procedures that had to be followed. Alyeska chose to be represented by Quinn O'Connell, a prominent DC attorney. They selected Von Rosenberg, who had actually developed the majority of the pipeline welding specification and was also serving that year as the president of the AWS (American Welding Society)., to present their testimony. He appeared as a witness at the hearings for two days, and presented the case that any defective welds would be found and repaired. Alyeska followed up this witness testimony by submitting their technical analysis and repair work report, and began to make repairs on the list. The final list of nearly 4,000 potentially defective welds and their scheduled inspections and repairs was later estimated to cost Alyeska in excess of $50 million.

Not to be outdone, President Gerald Ford then commissioned a Presidential Task force (PTF) to travel to Fairbanks, Alaska in mid-July of 1976 to witness a first-hand account of Alyeska's activities. Von Rosenberg was again chosen by Alyeska President E. L. Patton to give an accounting of the pipeline's safeguards and safety considerations to Mr. Barnum and other representatives of the PTF. The PTF needed proof of the integrity of the questionable welds, nearly all of them in Section 1 around the Brooks Range. While all of the exposed pipeline welds were inspected and repaired, if necessary, there were several welds under the Sagavanirktok (Sag) River just south of the Brooks Range which the committee insisted must be inspected and evaluated. To accomplish this difficult task, Alyeska had the above ground pipeline on either side of the river cut open, and large fans were set in place to circulate air. First the six foot six, 240 pound "Tiny" Von Rosenberg and Alyeska President Patton entered the pipeline and traveled on a wheeled trolley powered by a modified John Deere mower engine as proof of its safety and viability. When they came back a team of twelve men and inspectors followed suit, counting the numbers of joining welds as they traveled. When they reached the pipe welds in question under the Sag River, each of the welds was ultrasonically (U/T) inspected. The team exited the pipeline on the opposite side of the Sag River, and the pipe weld U/T information was taken back to a nearby camp for evaluation.

Alyeska felt confident that most of the questionable welds involved only the pipeline in and around the areas of the Sag River and Atigun Pass. For instance at Atigun Pass just south of the Sag River workers had to deal with permafrost and glacial soils. Since this pass was the site of frequent avalanches, an elevated pipeline was not a possible option. The engineers solved this problem by designing a reinforced, insulated ditch in which to lay the pipeline. That portion of the pipeline is encased in a 1 1/8 mile long concrete box lined completely around by almost two feet of styrofoam. The box was built and the pipeline was set in place before the first snowfall in October of 1976.

In the meantime nearly every Congressional sub-committee member seeking publicity was attempting to hold hearings at the expense of Alyeska. Von Rosenberg was summoned to a press conference in Washington near the end of July of 1976 where he outlined Alyeska's pipeline problems and reported on their progress. Then for the next two days he offered testimony to sub-committees chaired by Representatives John Melcher of Montana and Albert Johnson of Pennsylvania. Those two days of hearings were followed on the fourth day by meetings with the Department of Transportation headed by William T. Coleman in the morning, and the with the Department of the Interior in the afternoon with their new Secretary Thomas Kleppe, who had been appointed by President Gerald Ford,. The House and Senate were up for grabs due to the resignation of President Richard Nixon two years prior, and the Democrats planned to take control of both houses that year, which they did. Unfortunately, Alyeska was in the crosshairs of many of the politicians during 1975-1976 who were seeking election or re-election.

The Alyeska Task Group had spent many hundreds of man-hours planning the flow of oil over the 800-mile route from Prudhoe Bay to the Valdez Terminal, and were very confident of their basic design, their welding specifications, and the equipment that had been selected and. Many of the committee members learned for the first time that the pipeline was not one contiguous run of pipe, but rather was interspersed with over 175 strategically placed gate valves (block valves), flow control valves, and check valves. The 48-inch Cameron gate valves were castings of steel and were installed to stop any potential downstream oil leaks. Their function was to protect the environment in the event of any kind of oil spill or oil leak. There were block valves installed north of most of the streams and both north and south of each of the major rivers, including the Sag River and the Tanana River. Block valves were also located behind and ahead of the bridge crossing the Yukon River, and block valves were located in the pipeline before and after each pump station in order to isolate the pump stations during maintenance shutdowns.

The 48-inch Grove check valves were manufactured from fabricated steel, were located in strategic locations where the pipeline began a gradual uphill rise or started a steep uphill climb. Although these valves acted as backflow preventers to curtail any potential upstream oil spills, they did not inhibit forward flow. There were only minor drops in pipeline pressure across these check valves. The flow control valves, which were also furnished by Cameron, were precautionary valves that were placed in strategic positions where the pipeline either ran down a steep grade or else had a lengthy downhill run before it leveled off.

Presenting these facts coupled with his integrity and his candor helped Von Rosenberg during his numerous testimonies and in hearings before Congressional committees and Cabinet members. The truths that he revealed about the safety of the pipeline system plus his own knowledge and experience allayed any public concerns and fears. Von Rosenberg and Joe Willing, his immediate Alyeska supervisor, learned in these many hearings that they never had to worry about remembering something that they had said as long as what they had said was truthful. Von Rosenberg once made a special effort to bring clarity and validity to the concerns of the pipeline's construction by writing a detailed letter to Kent Frizzell, acting Secretary of the Interior under President Ford, regarding an environmental issue that had been discussed in the previous day's hearings.

4. Constructing the Pump Stations

Work at the pump stations initially lagged behind the construction of the pipeline. However, most of the pipeline camps had been set up in close proximity to the pump station locations so that work on the pump stations could proceed year-around. As with the campsites and worker housing, the pump stations were laid on large gravel beds in order to prevent contamination from any potential oil spills. Pump Station No. 1 received special attention due to the fact that it was controlling oil flow from the North Slope oil fields as well as initial oil flow into the pipeline. Despite the fact that temperatures reached near-record lows in the -70°F range, work under the supervision of Fluor-Alaska continued through the winter.

Pump Station No. 12 just north of the Valdez Terminal was another unit that was given priority due to its critical location near the port. However, Pump Station No. 6, which was one of the original five pump stations that would be needed at startup due to a reduced oil flow, was discovered to be on permafrost. Consequently it had to be elevated and redesigned, including having the requirement for insulation on all the components which processed and controlled the pipeline's oil flow.

Pump Station No. 11 was designed as a part of the original system by Alyeska and Fluor, but Alyeska believed that it would not be necessary. Of the eleven pump stations that were constructed, eight stations were tested and cycled and ready for initial operation when the first oil production through the pipeline began. The other three pump stations were completed at a somewhat less frenetic pace by the end of the summer of 1980 as oil flow through the pipeline increased.

According to sources from Alyeska and Roteq-Alaska, there were a total of twenty-eight pumps and other oil field equipment purchased for the original project through Flowserve, the parent company of several manufacturers. At least nineteen of the pumps were purchased from United Centrifugal Pump, Inc., including the initial pump that was purchased in 1970. Another nine pumps came from Byron-Jackson Pumps, which later became a division of the Borg-Warner Corporation.

The original design concept was to install three pumps in each pump station, with an area set aside in each pump station for a fourth pump if necessary. However, the three pumps in each station proved to be more than sufficient to manage the required oil flow through the pipeline. The last three pump stations constructed only required two pumps in total, and each of the pumps was driven by a Rolls-Royce natural gas turbine. Pump Stations Nos. 2 and 7 had the capacity to move oil at the rate of 60,000 gallons per minute, while the other pump stations, including No. 12, had the capacity of only 20,000 gallons per minute

5. Constructing the Valdez Terminal

Construction at the Valdez Marine Terminal, the southernmost point of the Trans-Alaska Pipeline, began in the fall of 1974. Although the Alyeska Task Group was involved in most of the material and welding specifications, they relied much more on the overall design and management capabilities of Fluor than they had with Bechtel Corporation on the oil pipeline. Numerous detailed surveys had shown that the site that was planned across the inlet from Valdez proper had a bedrock depth of only about six feet below ground surface. However, when their subcontractors began to excavate, Fluor and Alyeska discovered that the bedrock was nearly sixty feet below the surface of the ground. This required the removal of more than 10 million cubic yards of waste material and required major design modifications to the foundations that were supporting the holding tanks. Huge retaining walls had to be built around the area housing the terminal and numerous concrete columns were constructed to support all the tanks and other terminal structures.

Each of the holding tanks as specified by Fluor, with major input from the Alyeska Task Group, was required by the Pipeline Authorization Act that was signed into law in late 1973 to have the capacity equal to that of the total volume of the oil pipeline. Although the rationale for that logic was never fully explained, that requirement would allow the entire pipeline to be emptied into any of the holding tanks if that ever became necessary. The holding tanks were built by Chicago Bridge and Iron, and were subjected to rigorous non-destructive testing on their metallurgy as well as their welded structures and their flanges by the Battelle Institute.

Nevertheless, the Valdez Marine Terminal has the capacity to store more than 9 million barrels of oil, utilizing all eighteen storage tanks to provide this capacity. Each of the tanks is 250 feet in diameter and has a height of roughly 63 feet. There were also three power generating stations constructed at the terminal, and each power plant had the capability to generate approximately 12.5 megawatts of power.

The terminal proper was designed and built to have four oil tanker berths, with space for a fifth if ever needed. The Pipeline Authorization Act also required that a ballast filtration system be designed and built that would remove oil from the ballast water of the tankers. The local area fishermen had voiced their very logical concerns years before final approval that any contaminated water would destroy the fishing in Prince William Sound just south of Valdez, which empties into the Gulf of Alaska.

Because of the better climate in the Valdez area, the construction was also able to proceed year-around. Although construction was only about two thirds complete by the end of September of 1976 and still lagged behind the pipeline construction, terminal construction was able to continue through the winter months, resulting in the shipping berths being completed in late November of 1976 . Additional workers were brought into the terminal and, by the end of 1976, all structures had been completed and most of the equipment had been set, tested, and was operational. During the month of December, 1976, control computers were installed and programmed in the Valdez Operations Center, and the first signal was sent out to Pump Station No. 2 forty miles south of Prudhoe Bay. Owing to the Marine Terminal being the lagging portion on the construction schedule, work continued on the terminal through the winter of 1976 and into the first three months of 1977.

Construction Completion

The project was on average about 90% complete when 1977 began, and the few tasks necessary to complete the pipeline construction had been identified. Most of the eleven pump station structures had been completed by the construction companies and independent workers. Eight of the pump stations had been hydrostatically and electronically tested, and had been turned over to Alyeska operations personnel. The Valdez Marine Terminal was functional and mostly operational by the end of March, and Alyeska had begun cleanup and environmental remediation as prescribed.

Associated-Green, which had performed so well with their construction tasks on the pipeline, was assigned to complete the remaining tasks on the pipeline proper. They completed hydrostatic testing of the last 150 miles of the pipeline, and made thirty-three remedial welds to the pipeline joints that were left over from 1976. They reinsulated about forty-five miles of the pipeline that hadn't been done properly, and performed a few other minor tasks as requested. On 30 May 1977 the Task Group received word that the last pipeline weld had just been made, and the Trans-Alaskan Pipeline was ready for operation

D. Summary

Startup

Based on Frank Moolin's progress report, Alyeska gave notice that they intended to begin filling the oil pipeline sometime toward the end of June, 1977. Alyeska's original proposal was to start with a capacity of six hundred thousand barrels per day, and to ramp up to 1.2 million barrels per day within a two year period. While their long-term objective was to get to two million barrels per day at some time in the future, the OPEC oil embargo caused a major change in Alyeska planning. Their new objective was to begin producing approximately double the original amount of oil, which would then require at least eight pumping stations to be ready at startup.

Their engineers realized that there were some serious challenges when they would begin to fill the pipeline:

1. There was a need to balance the temperatures between the oil at Prudhoe Bay, which would be entering the pipeline at more than 120°F, and the temperature of the air-filled pipeline, which was nominally at about 20°F. The engineers feared, maybe rightfully so, that the pipeline could crack in some places due to sudden thermal expansion.

2. There was a need to purge as much air out of the pipeline as possible in order to reduce the risk of either a fire or an explosion. Normally an oil pipeline was filled with water, and then the ensuing oil flow would push the water out of the pipeline, but the fear of the engineers was that the water would freeze due to the temperature of the pipeline.

Both problems were resolved by purging the line with nitrogen gas, a much lighter than air or water chemical that does not support combustion nor freeze at normal temperatures. On 20 June 1977 at 10:06 a.m. (Fairbanks, Alaska time) the first section of the pipeline was pressurized with nitrogen and North Slope oil was introduced behind it. The initial flow of oil was inordinately long, finally reaching the terminal at Valdez on 28 July 1977 at 11:02 p.m., having a temperature of about 45°F. The Alyeska operations engineers were extremely cautious during this initial stage, doing their best to introduce the oil at a slow pace in order to control oil flow down some of the steeper inclines, under the many streams, and across the river pipeline bridges.

As the oil proceeded through the pipeline, it was followed closely by various groups of Alyeska inspectors traveling the pipeline route and looking for any signs of leaks, settling of the pipeline, or indications of movements in any of the supports and bridges. The startup was not without any problems, with one of the incidents that occurred being minor in nature, while the second incident resulted in numerous injuries and a fatality. On 05 July a minor nitrogen leak was detected in the main pipeline near Pump Station No.8 just south of Fairbanks. The flow of oil was curtailed for 1 1/2 hours while a repair crew of welders and workers repaired an elbow that had been cracked due to the temperature differential between the pipe and the nitrogen purge.

Then on the next day oil flowed accidentally through a block valve that had not been completely closed ahead Pump Station No. 8 as Alyeska employees were replacing a pump strainer. The resulting oil spray mixed with ambient air formed a deadly mixture, and was ignited by a stray spark that caused a major explosion. One worker was killed and five others were hospitalized as a result, and Alyeska's Task Group was dispatched to Fairbanks to determine the cause of the explosion and to develop procedures to prevent accidents of this nature in the future. Pump Station No. 8 was shut down for the next eight months while it was being repaired and all remedies were being pursued.

Construction continued with limited crews of sub-contractors and workers on the remaining pump stations, the Yukon River Bridge, and remediation of the many camp sites and pipe storage areas. However the project came to an official end, and the Task Group cleaned out their pipeline files, on 01 August 1977 when the tanker ARCO Juneau sailed out of the Valdez Terminal with the first shipload of oil from the Trans-Alaskan Pipeline, estimated to contain about 825,000 barrels of North Slope crude oil.

Project Cost

The TAPS Task Group and management from the Big Three of Atlantic-Richfield, Humble Oil & Refining, and British Petroleum had gotten together in the summer of 1969 to prepare a budget and a project cost for the Trans-Alaskan Pipeline. Their initial proposal to their investors was $900 million, and was based on the project construction beginning in the spring of 1970 and being completed sometime in 1972 Included in this original estimate was the cost of $100 million for the 4- inch pipe, which at the time seemed high. Following several unplanned delays due to numerous environmental objections and other reasons previously described, the cost of the project began to increase dramatically

Subsequent to the incorporation of Alyeska in late 1970, three years of legal battles and numerous design modifications ensued, and a period of significant inflation also occurred. In fact inflation had become such a national issue that numerous price controls were invoked on several products in the United States. In the fourth quarter of 1973 during the oil embargo by OPEC, Alyeska's Task Group revised its cost estimate to a still realistic number of $3.5 billion. One year later, after recognizing that inflation had largely affected union labor rates as well as products and materials, Alyeska's Task Group again revised their estimates to a whopping $6 billion.

In July of 1976 as the third year of construction was getting underway and most of their materials and equipment was either delivered or committed, Alyeska's Task Group and Construction Managers from Bechtel and Fluor got together to provide what they hoped would be a final project cost estimate of $7.7 billion. This figure was important to Alyeska management, inasmuch as they were looking for a three year return on their investment and, therefore, needed to know how much oil they should be processing through their pipeline. The final construction cost of $8 billion, which is the most common number associated with the Trans-Alaska Pipeline, may not have extended actual costs beyond 01 August 1977. Following that date several hundred million dollars were spent to complete the pump stations and for the cost of repairs and improvements.

Most Project Managers put together a project cost estimate based on the price of known equipment and commodities. Then they get bid estimates on the cost of construction, followed by a contingency allowance, depending on known values of the project. The more you know about the cost of a project, the lower your contingency figure, and visa versa. Some projects that have firm quotes and/or valid budget prices, may have contingencies as low as 4%. Other projects might be riskier or have more unknown values, and their contingencies could be justified to be as high as 15% to 18%.

Two other factors in preparing a project cost estimate are **inflation** and **design finalization.** In the case of the Trans-Alaskan Pipeline, inflation was a huge contributing factor to the high cost, with an estimated impact of more than $2.5 billion. However, numerous design modifications had to be made due to the terrain and the weather as well as the environment, and these factors certainly should have been considered in the initial project costs. Consequently, these types of necessary changes in design from the original thinking probably added another $1.5 to $2.0 billion

Future of the Gas Line

For the entire eight years that the Trans-Alaskan Oil Pipeline was first considered, then held up by litigation before finally starting to produce oil flow, the Big Three and their engineers held hope of receiving approval for a parallel natural gas pipeline. They recognized that the North Slope Oil Fields would hold billions of cubic feet of natural gas, and the TAPS Task Force which morphed into the Alyeska Task Group was assigned to determine a way to get that natural gas to market. They continued to meet with potential suppliers of 48-inch pipe, valve manufacturers, and testing agencies. However, the further that the Task Group planned, the more that the justification became unrealistic and the ultimate cost became prohibitive.

Natural Gas in its raw state is primarily methane gas, but does have small percentages of useless, and potentially damaging, contaminants such as water, hydrogen sulfide, and other elements that would require a processing plant at the North Slope. A pump station would also be needed to begin the transport of the gas, but it would have to be a different type of pump in order to compress the gas and initiate its flow process. While fewer pump stations would be needed along the gas pipeline route, a liquefied natural gas plant would have to be built at Valdez, and more ship berths would be required in an already crowded harbor.

Options that the Task Group considered included:

1. transmitting the gas to Fairbanks, building a gas liquefaction plant there, and transferring the LNG by tanker truck to the mainland through Canada.

2. transmitting the gas to Fairbanks, and building a gas pipeline through the Yukon Territory of Canada and into British Columbia, where it would connect with existing natural gas pipelines.

As both of these alternatives relied on Canadian approval, Von Rosenberg attended numerous hearings at the National Energy Board of Canada in Ottawa, and gave detailed testimonies of Alyeska's plans. Several other Alyeska executives and engineers attended these hearings, as well, over a five-year period as they continued to seek approval to harvest the enormous amount of natural gas that would be coming available. However, the "death knell" for the natural gas pipeline concept being abandoned and relegated to the politically correct burial ground came in an NEB meeting report on 05 July 1977. In this meeting which was more than likely attended by members of the Carter Administration, the NEB believed that truck safety was paramount, and that the cost to rebuild the necessary roadway infrastructure was prohibitive. They also refused to allow the gas pipeline to be routed through Canada, and then into the united States, seemingly for environmental reasons. The Energy Board had the authority to make such a determination that would affect the State of Alaska as well as our other forty-nine states.

In the interim one American company (United States Steel) did invest more than $65 million in a plant at Baytown, Texas that would produce 48-inch outside diameter pipe for the natural gas pipeline. In 1975 they brought the presses and other tooling necessary to produce 48-inch diameter, X-72 (72,000 psi yield strength) pipe from an American Bridge Fabrication Shop in Orange, Texas. The new mill was to be highly automated and would have a production rate that was more than two times greater than the Japanese plants which had been contracted to produce the pipe for the oil pipeline. Von Rosenberg visited both the Baytown and the Orange plants on consecutive days, and was eager to see the Baytown Pipe Mill be completed and begin to produce 48-inch product. Nevertheless, by the time of the new mill's startup in October of 1977, the oil pipeline was already in operation and the plans for an arctic natural gas pipeline had been shelved. The SAW Mill at Baytown was eventually sold to a steel company from India for pennies on the dollar.

Current Status of the Pipeline

Although Alyeska Pipeline Services Company began pumping oil in June of 1977, it never really had a major impact on oil prices around the world. The two primary reasons were that the pipeline took several years to reach full production, and partly because oil production in the Continental United States reduced dramatically as oil prices fell to pre-pipeline levels in the late 1980's.

At about midnight on 24 March 1989, the Exxon Valdez oil tanker bound for Long Beach, California and carrying upwards of one million barrels of oil, struck a reef in Prince William Sound. The resulting oil spill was the largest oil spill in the world up until the time of the B/P Deepwater Horizon catastrophe off the coast of Louisiana in 2010. What made this oil spill so devastating was that the remoteness of Prince William Sound makes it inaccessible except by ship or seaplane. The region was a natural habitat for salmon and herring spawning as well as for sea otters, seals, and various seafowl. The law was changed to require all tankers to be escorted by two tugboats through the Sound until they are into open waters. Most of the natural habitat has returned to near-normal after all these years, but there is no longer any fishing for herring, a regulated fishery industry, in Prince William Sound.

Since 1990 nearly all of the original pumps have been replaced by pumps from Sulzer, a Swiss-based company. Of the remaining four or five pump stations still in operation, the pumps are now driven by electric motors sourced from nearby power grids. This has been made possible by two important factors: a drag reduction additive (DRA) is now introduced into the system to substantially improve the oil flow, and the remaining four or five pump stations are sufficient for the current oil flow, which is only about twenty-five percent of the original projection.

Future for Alyeska

As of 2016 Alyeska has pumped more than 17 billion barrels of crude oil through the Alaskan Pipeline, and it currently supplies about seventeen percent of the nation's crude oil. Oil going into TAPS comes from several oilfields along the North Slope, including the Prudhoe Bay Oilfield, and is transferred through a series of feeder pipelines before reaching Pump Station No. 1. Presently the crude oil travels an average of twelve days before arriving at the Valdez Terminal, even though the current rate of flow has been reduced to as low as 509,000 barrels per day versus its initial rated capacity of slightly more than two million barrels per day.

In addition to Pump Station No. 1 operating, there are currently only four other pump stations in operation. Two of those pump stations have the ability to move the crude oil at the rate of 60,000 gallons per minute, while the other two pump stations in operation each have a capacity of only about 20,000 gallons per minute. Although flow rates through the Trans-Alaskan Pipeline continue to be reduced, exploration continues to discover new oilfields. In addition new drilling technology continues to reach still-untapped regions where crude oil exists.

Another long-range possibility for Alyeska is ANWR, the Alaskan National Wildlife Refuge. Whether to drill for oil in this region, which is located in the extreme northeast part of Alaska, has been a running political controversy since TAPS first began to produce oil. Although drilling there would involve about one and a half million acres, this represents less than 8 % of ANWR's total acreage. However, environmentalists and biologists have propagated numerous theories as to why drilling for oil in this region would adversely affect herds of Porcupine Caribou and Central Arctic Caribou. This controversy will undoubtedly continue in our lifetime, or at least until the next OPEC oil embargo. In the meantime Alyeska Pipeline Services Company, operating at close to 100 percent reliability, will continue to operate at a reduced crude oil capacity, possibly for the next twenty to forty years.

America's Greatest Projects & Their Engineers-III – QUIZ

1. The Richfield Oil Company had drilled five successful oil wells in North Alaska by:
   a. 1950.
   b. 1965.
   c. 1968.
   d. 1969.

2. Which of these companies was not a member of the original TAPS group:
   a. Humble Oil
   b. Esso
   c. Atlantic-Richfield
   d. Sunoco

3. The original TAPS plan called for a:
   a. two hundred foot right-of-way.
   b. 100 foot right-of-way for the oil line and a 100 foot right-of-way for the gas line.
   c. 100 foot right-of-way for the oil line and a 100 foot right-of-way for the maintenance road.
   d. 100 foot right-of-way for the gas line and a 100 foot right-of-way for the maintenance road.

4. What is the inside diameter of the bottom dies of a U-Press that produce 48-inch O.D. pipe by .500 inch wall thickness?
   a. 48.5 inches.
   b. 48.0 inches
   c. 47.5 inches
   d. 47.0 inches

5. One of the big advantages of the Japanese pipe mills was that they could manufacture SAW pipe in:
   a. 60 foot lengths.
   b. 65 foot lengths.
   c. 70 foot lengths.
   d. 75 foot lengths.

6. The first shipment of pipe for the Trans-Alaskan Pipeline left:
   a. Sumitomo on 29 August 1969.
   b. Sumitomo on 29 August 1970.
   c. Yawata on 29 August 1969.
   d. Wakayama on 29 August 1970.
   e.

7. One of the biggest challenges of the TAPS project was how to deliver 167 miles of pipe to:
    a. the Kenai Peninsula.
    b. Pt. Barrow.
    c. the North Slope.
    d. the Brooks Range.

8. The amount of time available to move pipe across the Arctic Ocean to the North Slope was:
    a. all of July and August.
    b. forty days in August and September.
    c. all of August and September.
    d. forty days in September and October.

9. The route chosen by the TAPS survey team of engineers was:
    a. fairly level.
    b. relatively straight.
    c. easy to navigate.
    d. none of the above.

10. The newly formed Alyeska Pipeline Services Company hired Bechtel Corporation to:
    a. design and construct the pipeline.
    b. design and construct the pump stations.
    c. provide design and construction management for the pipeline.
    d. provide design and construction management for the pump stations.

11. Quench and Temper product must contain a certain amount of:
    a. carbon and magnesium.
    b. ferrite and aluminum.
    c. ferrite and carbon.
    d. graphite and carbon.

12. A typical example of non-destructive testing procedures is:
    a. fluoroscopy.
    b. x-ray.
    c. ultrasonics.
    d. all the above.

13. Max Brewer presented evidence that burying the pipeline would:
    a. cause the support of the pipeline carrying hot oil to fail.
    b. require more gravel under the supports.
    c. require the supports to be flushed with nitrogen.
    d. limit the number of supports for the pipeline.

14. Under the Alaskan Native Claims Settlement Act:
    a. Native Alaskans received $1 billion from the State of Alaska.
    b. Native Alaskans were each given $150,000 from the Federal Government.
    c. Native Alaskans had to waive all of their land claims without any compensation.
    d. none of the above.

15. The Arab-led oil embargo in mid-October of 1973 caused the United States to lose:
    a. one-fourth of its oil supply.
    b. one-third of its oil supply.
    c. one-half of its oil supply.
    d. nothing, because the United States was self-sufficient.

16. In addition to crossing over the Denali Fault, the Trans-Alaskan Pipeline had to cross over or under:
    a. more than 500 rivers and streams.
    b. several Native Alaskan burial grounds.
    c. more than 300 rivers and streams.
    d. more than 500 caribou grazing grounds.

17. Although the original plan called for the Trans-Alaskan Pipeline to be buried:
    a. only about five miles of the pipeline was buried.
    b. about one-half of the pipeline was built above the permafrost.
    c. about one-half of the pipeline was buried in river beds.
    d. none of the above.

18. The Denali Fault presented specific problems because:
    a. the pipeline had to be built in a straight line.
    b. the pipeline could not be insulated in this area.
    c. the pipeline had to be built above the permafrost.
    d. engineers could not find a material on which the pipeline could slide.

19. The storage tanks at the Valdez Terminal have the capacity to hold:
    a. two million barrels of oil.
    b. four million barrels of oil.
    c. six million barrels of oil.
    d. all of the oil in the pipeline.

20. The cost of the Yukon River Bridge was paid:
    a. Two-thirds by Alyeska and one-third by the State of Alaska.
    b. One-third by Alyeska and two-thirds by the State of Alaska.
    c. Two-thirds by the State of Alaska and one-third by the Federal Government.
    d. One-third by Alyeska and two-thirds by the Federal Government.

21. The welders who performed the task of welding the pipeline proper were mostly :
    a. native Alaskans.
    b. Teamsters.
    c. employees of The Bechtel Corporation.
    d. Local 798 members from Tulsa, Oklahoma.

22. Even though the project had a no-strike policy, the Teamsters were able to shut the project down for four days because:
    a. the supply of tools ran out.
    b. certain roads were too hazardous for safe travel.
    c. the weather became treacherous.
    d. many of the Teamsters were from Southern California.

23. Frank Moolin made news in 1976 by:
    a. being named Man-of-the-Year by Engineering News Record.
    b. terminating the cost-plus contract of The Bechtel Corporation.
    c. adding incentives that accelerated the pipeline construction schedule.
    d. all the above.

24. The engineers solved the problems at Atigun Pass by placing the pipeline is a concrete encasement and lining it completely around by almost two feet of:
    a. Styrafoam.
    b. rubber.
    c. wet gravel.
    d. glacier ice.

25. The original plans called for twelve pump stations:
    a. and all twelve were built.
    b. but only eleven were ever built.
    c. but Pump Station No. 1 was never built.
    d. and No 12 Pump Station was the last one built.

26. Each of the storage tanks at the Valdez Marine Terminal has the capacity of about:
    a. 1 million barrels of oil
    b. 850,000 barrels of oil..
    c. 500,000 barrels of oil.
    d. 100,000 barrels of oil.

27. The Alyeska objective at startup in 1977 was to begin producing approximately:
    a. 600,000 barrels of oil per day.
    b. 1.2 million barrels of oil per day.
    c. 2.0 million barrels of oil per day.
    d. as many barrels of as they could.

28. The first oil tanker, the Arco Juneau, sailed out of the Valdez Terminal on:
    a. 20 June 1977.
    b. 05 July 1977.
    c. 28 July 1977.
    d. 01 August 1977.

29. As of 2016 Alyeska has pumped more than:
    a. 20 billion barrels of crude oil through the Alaskan Pipeline.
    b. 25 billion barrels of crude oil through the Alaskan Pipeline.
    c. 17 billion barrels of crude oil through the Alaskan Pipeline.
    d. 18 billion barrels of crude oil through the Alaskan Pipeline.

30. One result of the Exxon Valdez oil spill was:
    a. each tanker leaving the Valdez Terminal must be accompanied into open water.
    b. the Exxon Valdez was permanently put into dry dock.
    c. Alyeska immediately cut back on their oil flow through the pipeline.
    d. the Alaska fishing industry didn't suffer any losses.