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SWELT – TECHNOLOGY OF WAVE ENHANCED TRANSPORTATION OF VISCOUS AND ULTRA-VISCOUS OIL VIA PIPELINES

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SWELT – is a technology of wave enhanced pipeline transportation of viscous and ultra-viscous liquids and other liquids.

SWELT – applies waves of certain characteristics to viscous and ultra-viscous oiland natural bitumen when they are transported via pipelines. As the result of the treatment hydraulic resistance of the pumped through the pipeline oil is effectively reduced, which resolves series of problems. In particular, SWELT provides the following resolutions and possibilities:

- *increase of volume of transported substances (oil, natural bitumen, etc.). The greater the hydraulic resistance in the base case of pumping, the greater the effect achieved with SWELT treatment;*
- *reduction of pumping pressure at the booster pump of the pipeline;*
- *reduction of quantity of booster stations along the pipeline and increase of distances between the booster stations;*
- *reduction in needs to heat the pipeline in purpose of reduction of viscosity of the transported liquid.*

Besides, SWELT delivers additional pushing force in direction of pumping that provides for additional increase of the volume of transported fluid, or further reduction of pumping pressure.

SWELT does not change the composition of the transported substance. The technology is safe for personnel, environment and the equipment.

Technology SWELT is proprietary to GALEX Energy Corporation.

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KEY WORDS: *SWELT, wave treatment of pipeline transported oil, wave enhanced transportation of liquids, pipe waves, Galex Energy Corporation.*

SWELT – ТҰТҚЫР СҰЙЫҚТЫҚТАРДЫ ЖӘНЕ СУСЫМАЛЫ СУБСТАНЦИЯЛАРДЫ ҚҰБЫР ЖЕЛІЛЕРІ АРҚЫЛЫ ТОЛҚЫНДЫ ТАСЫМАЛДАУ ТЕХНОЛОГИЯСЫ

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SWELT – бұл тұтқыр және ультра тұтқыр сұйықтықтарды және сусымалы заттектерді құбыр желілері арқылы тасымалдауға арналған толқынды ынталандыру технологиясы. Сорып алынатын заттекке толқындар арқылы әсер етудің нәтижесінде құбыр желісі арқылы тасымалданатын заттекті сорудың гидравликалық кедергісін айтарлықтай төмендетеді, бұл туындаған мәселелер мен кедергілер кешенін шешуге мүмкіндік береді. Атап айтқанда, SWELT пайдаланушыларға келесі шешімдер мен мүмкіндіктерді ұсынады:

- *құбыр желісі арқылы тасымалданатын заттектің көлемін арттыру (мұнай, пульпа және т.б.). Заттекті тартудың негізгі нұсқасындағы гидравликалық шығындар неғұрлым көп болса, SWELT технологиясын қолданғанда бұл нәтиже соғұрлым көп болады;*
- *тұтқыр және сусымалы заттектерді тасымалдау кезінде сору қысымын азайту;*
- *құбыр желісінің бойында орналасқан тіреулік станциялардың жиілігін және санын қысқарту;*
- *тасымалданатын сұйықтықтың тұтқырлығын азайту үшін құбырды жылыту қажеттілігін азайту.*

Сонымен қатар, SWELT сорғы бағытында қосымша толқынның күшеюін қамтамасыз етеді, бұл тасымалданатын заттектің көлемін ұлғайтуға немесе сору қысымын төмендетуге мүмкіндік береді.

SWELT тасымалданатын заттектің құрамын өзгертпейді, қызметкерлерге, қоршаған орта мен жабдықтарға қауіп төндірмейтін технология болып табылады. SWELT технологиясы GALEX Energy Corporation компаниясына тиесілі.

НЕГІЗГІ СӨЗДЕР: *SWELT, мұнайды тасымалдауды толқынды ынталандыру, тұтқыр мұнайды құбыр желісі арқылы тасымалдау, сұйықтықтарды толқынды тасымалдау, құбыр толқындары, GALEX Energy Corporation.*

SWELT – ТЕХНОЛОГИЯ ВОЛНОВОЙ ТРАНСПОРТИРОВКИ ВЫСОКОВЯЗКИХ И УЛЬТРАВЯЗКИХ НЕФТЕЙ ПО ТРУБОПРОВОДАМ

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SWELT – это технология волнового стимулирования, предназначенная для трубопроводной транспортировки вязких и ультравязких жидкостей (нефтей). В результате воздействия на прокачиваемую среду волнами резко снижаются гидравлические сопротивления прокачки транспортируемой нефти, что обеспечивает решение комплекса проблем и препятствий. В частности, SWELT предлагает пользователям следующие решения и возможности:

- *увеличение количества транспортируемой по трубопроводам жидкости (нефть, битум, пр.). Чем больше гидравлические потери при базовом варианте прокачки, тем больший эффект достигается при использовании технологии SWELT;*
- *уменьшение давления прокачки при транспортировке вязких и сыпучих сред;*
- *уменьшение частоты и количества подпорных станций на протяжении трубопровода;*
- *уменьшение потребности прогрева трубопровода, в целях снижения вязкости транспортируемой жидкости.*

Кроме того, SWELT обеспечивает дополнительное волновое усилие в сторону прокачки, что позволяет увеличить объем транспортируемой среды, либо снижает давление прокачки.

SWELT не изменяет состав транспортируемой среды, является безопасной технологией для персонала, окружающей среды, оборудования.

Технология SWELT является собственностью GALEXEnergyCorporation.

КЛЮЧЕВЫЕ СЛОВА: *SWELT, волновое стимулирование транспортировки нефти, транспортировка вязкой нефти трубопроводами, волновая транспортировка жидкостей, трубные волны, GALEXEnergyCorporation.*

SWELT TECHNOLOGY OFFERS USERS THE FOLLOWING BENEFITS:

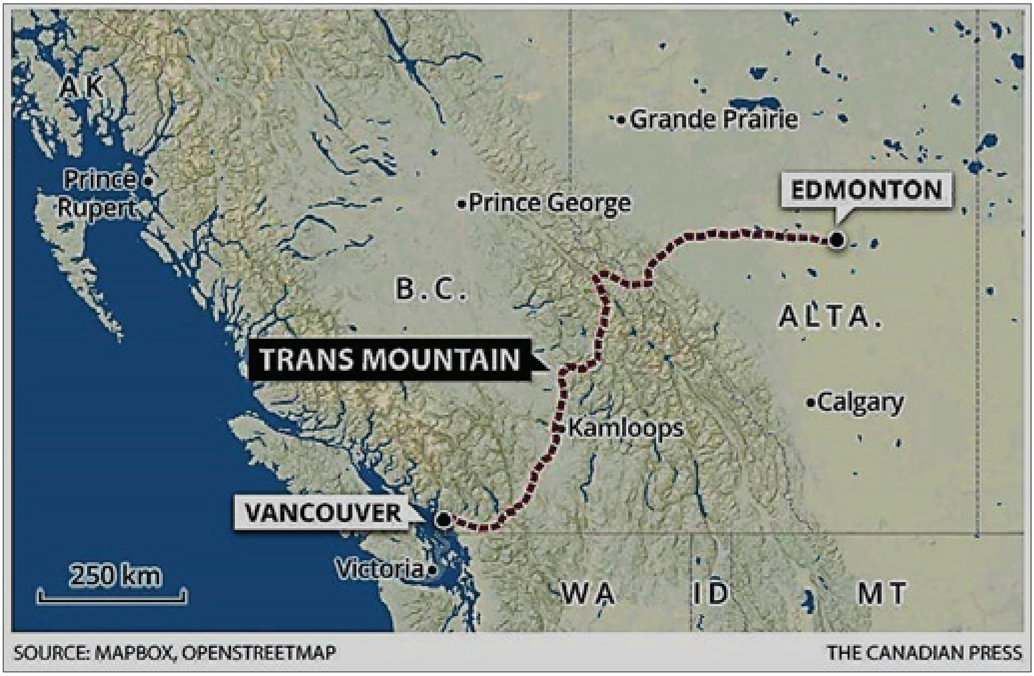
- ***increase in the volume of liquids transported through pipelines (oil, bitumen, etc.). The greater the hydraulic losses in the base case of pumping, the greater the effect achieved with the use of technology SWELT;***
- ***reduction of pumping pressure when transporting viscous and ultra-viscous oil;***
- ***reduction of quantity and frequency of installation of booster stations along the pipeline;***
- ***reduction of the need of heating the pipeline in order to increase mobility of liquids transported through it.***

Transportation of high-viscosity oil via pipelines has always been a challenge. High viscosity oil often produced using thermal methods is mobile while heated but jells up and becomes immobile when the heat is lost. It is clear that such pumping of oil through the pipeline requires large expenses on heating of the pipes and maintaining pressure needed to move the oil through the pipeline. This is particularly relevant in areas of the Arctic and cold climate, such as northern Kazakhstan, Siberia, Canadian provinces Alberta, Saskatchewan, Athabasca, where such transportation of oil in the winter is especially expensive and requires a lot of additional costs for keeping of the pipelines in working order.

Need to transporting heavy and viscous oils increased greatly in recent times. In the United States, for example, in connection with the increase of production of the ultra-light shale oil, and fact that the main Texas Gulf coast refineries, remain tuned to the medium grade oil, increases the need for heavy sulphurous oil for blending with a light shale oil so the oil midstream companies meet the refineries' required specifications. The collapse of the oil industry of Venezuela, traditionally one of the largest suppliers of heavy oil, the protracted problems of Mexico oil industry, impose additional requirements to increase the production and supply of heavy oil from Canada, develop the United States, preferably the Texas based, heavy oil basins that had been long time overlooked due to, among other challenges, difficulties in pipeline transportation. In Kazakhstan, Russia, other countries there is also growing needs for increasing the volume of production and transportation of heavy oil, reducing the cost of pumping.

In turn, the ability of Canada to increase the supply of heavy viscous crude oil in the United States are constrained by the throughput capacity of Keystone XL pipeline. The debate on enlargement of which has been going on for a long time, but finds no resolution because of the rigorous position of the indigenous people on the paths of the pipeline and the environmentalists. Canada's attempts to get approval to extend another, the Trans Mountain Pipeline, from Edmonton, Alberta, to Vancouver, BC *(figure 1)*, for the same very reason resolution could not be permitted either until very recently. However, based on the experience with the Keystone XL pipeline approval, it is anticipated that commencement of the construction of the pipeline will be strongly protested by the indigenous people so the construction permit could be aborted.

These factors limit the growth of heavy oil production in Canada, negatively impacts on the economics of oil producing companies in Canada developing the heavy oil reserves, damages the country's economy as a whole. The debottlenecking in the oil marketing could



SOURCE: MAPBOX, OPENSTREETMAP THE CANADIAN PRESS

Figure 1 – **Path of Trans Mountain Pipeline extension. Approved by Canadian Government for construction on 18 June, 2019**

be found in ability to multiply the throughput capacity of the existing pipelines, which is equivalent to having several new pipelines laid next to the existing ones but without capital expenditures building them. But is it possible?

GALEX Energy possesses technology that addresses and efficiently resolves these problems. The technology has been tested and is proven by transporting not only highly viscous liquids, but even sand pulps, and therefore is called the technology for wave enhanced pipeline transportation of viscous liquids and other substances, although the main purpose of this invention is oil, including the ultra-heavy and the ultra-viscous oil, when the transportation is additionally complicated with oil gelling up in the pipeline due to extremely low temperatures. SWELT technology allows to multiply the volume of pumped oil, particularly viscous, while maintaining the base pressure in the pipeline. There is no need for heating up the pipeline to ensure the fluidity of oil through it.

When the objective is set to reduce the pumping pressure, SWELT is able to drastically reduce the pumping force on the pipeline and so to reduce the operation cost of the oil transportation.

THE FOLLOWING ARE THE ENGINEERING AND OPERATING PRINCIPLES OF TECHNOLOGY SWELT

Process of wave transportation of viscous liquids and sandy pulps is as follows. The SWELT wave generator is made up on the end of a special guide joint the other end of which is cut into the pipeline. The transported material via the special guide joint is pumped into the entrance of the pipeline with constant output making sure there is positive pressure has been built in the line. The transported material fills in the special guide joint and the sufficient pressure is transferred into the transducer of the SWELT wave generator. The SWELT generator is turned on starting the tube waves motions propagated into the pipeline by sending the predesigned elastic impulses from the transducer directly into the transported material so that the summary shifting force is realized in the direction of transportation. As the result of the force of each stroke the endface of the transducer applies to the transported material in shape of a pipe wave, which is equal to or greater than the pulse pressure, that is the driving force behind transported material (liquid or pulp), the material moves in a given direction. After the end of the stroke cycle of the transducer of the wave generator in the direction of transportation the transducer returns to its starting position and the cycle repeats.

Range of an elastic wave propagation in an uninterrupted liquid flow in a pipeline reaches tens of kilometers and even beyond that. When a shape of waves, their length, amplitude and other characteristics optimized to the pipeline specs, layout, terrain of the path, specs of the liquid in the pipeline the tube waves fade very slowly. Should the application be applied to a dry sandy material, waves attenuate much more intensely – on a length of under one kilometer.

The wave initiates into the transported fluid in a predetermined shape and parameters, such as pressure coordinates-wavelength, amplitude compatible, but in excess, to the hydraulic resistance inside the pipe at each stroke of the wave transducer. The fluid resistance changes in a distance equal to the wavelength and is calculated as the derivative of the excessive force applied to the transported liquid at each stroke. Such excessive force is calculated as a function of the speed of the stroke, transduced into the speed of the generated wave summarized with the speed of the transported fluid, which, in turn, is a function of pressure gradient on the length of the wave. Therefore, in order to maintain the predetermined pressure gradient on the linear section of the pipeline the wave impulse must be calculated on the basis of the following equations: **F=KV2,** where

F – *hydraulic resistance force of the transported material within the pipeline;*

V = V1 + V2 – *summary of velocity of the transported pipeline fluid and the velocity enhanced by the wave;*

V1 – *velocity of the fluid within the pipeline*

V2 – *added by the wave velocity;*

К – *adjustment factor for the transported fluid.*

Thus, the wave diagram at these cases should be in a form quadratic parabola. The value of wave pressure differential, applied to the transported liquid, that is equal to the wavelength, will be constant. So, the maximum energy efficiency will be achieved at each linear section of pipeline. In this case, an excess of the wave amplitude will compensate attenuation along the section of the pipeline during fluid transportation.

The shifting force of the wave impulse to the transported substance, and the shifting itself, directly depends on the excess of the wave amplitude over the ID of the pipeline at any given point of the pipeline. Should such excess come to zero due to the attenuation of the wave the shifting force also come to zero. In this case the enhancement of SWELT technology will be based only on the reduction of the hydraulic resistance of the transported substance in the pipeline.

If the algorithm of wave loading of a section of the pipeline with the transported substance in it is not compatible with the algorithm of hydraulic resistance, the material on the wavelength may be accelerated at the beginning of the wavelength, and at the end of this phase would slow down, which will not only be unproductive for the energy use but will also generate reciprocal axillary forces and movements that are bad for the pipeline. With the propagation of waves in the transported material within the pipeline it will be divided into heavy and viscous (the denser) the central part, which is surrounded by a ring of a lighter and more mobile fraction (and less viscous), which is placed on the periphery of the transported contact flow of the transported fluid to lubricate the walls of the pipeline. If needed, this lighter fraction may be collected into a separate reservoir at the end of the transportation. Moreover, as empirically confirmed in multiple tests and operations, the wave enhanced pipeline transportation of liquids and other substances is in direct relationships with the ratio of wavelength to the pipeline ID. The greater the ratio, the better the division of the flow into the outer lighter and the inner heavier fractions.

Wavelength also impacts the distance of transportation – the bigger the wavelength, the greater the range of its attenuation and so the transportation efficiency.

To ensure the transportation of liquid materials for pipe sections going up vertically or at an angle up the amplitude of pressure waves are chosen such that it is equal to not less than three values of pressure, which provides the vertical component of the force on height of transported material with height equal to the wavelength and frequency are chosen from the condition: **f*T = 0,8-1,0,** where

f – *frequency of the wave impulses;*

T – *timelength of each impulse.*

This condition provides the quantity of wave impulses at any given time repeated one after the other, in which the transported material being lifted to a height **h** by the passing wave impulse will manage to descend **0,8 h** down until the next wave reaches the material to lift give it another lifting impulse. This condition provides condition to calculate the density wave impulses repeated one after the other, so the transported material after its descend at each impulse will be moved up **0,2 h**, so the wave based enhancement of transportation of the material can be calculated.

When planning wave enhancement of transportation viscous liquids and other materials via pipelines the trajectory of the pipeline must be taken into account, in particular turns of the pipeline on the path. Calculations must ensure compliance with conditions of minimum energy loss, where the transported material is serving as the wave transmitter. Single dogleg turn should not exceed 30° from the direction of the velocity vector, initial movement and twist on a great angle provide multiple reflection waves on angle α, which is equal to the angle of incidence of the wave. When the single angle does not exceed 30°, it ensures complete refraction of wave energy in a given direction. If the angle exceeds 30° reflection wave appears, bearing the energy waves in the opposite direction. In order to flow by turning the provided refraction wave energy throughout the length of the bending of the knee are performing greater than or equal to the wavelength.

Compliance with the principles listed provides reusable energy transported along the liquid on the entire length of transportation throughout the length of the pipeline. In this case wave radiated by an angle of incidence waves, equal or lesser 30° to the axis of the transport pipeline. Should the pipeline contain sharp angles (30° or greater) and they may not be by-passed with strait lines, the pipeline may include a booster station on the enter into the turn and another wave generator just past the turn.

Thus, the technology wave transportation uses two physical principles of transporting of liquids by a pipeline. Firstly, it is a radical reduction of hydraulic resistance at the interface of transported material and the inner surface of the pipe. Transported material, in our case the viscous or even ultra-viscous oil, moves through the pipeline in the lateral shape. The peripheral portion of the liquid, that is connected with the internal wall of the pipe, is presented in the form of a layer of light fraction of oil serves as lubricant and minimizes hydraulic resistance of moving the oil through the pipeline. Secondly, it is directly wave transportation, in which the impulse wave configuration is chosen in such a way as to create total progressive force in the direction of the transportation. This is especially important when crossing the high-amplitude areas, such as mountain crossings.

When properly designing SWELT application, such as configuration, length, amplitude and frequency of the waves, frequency of wave impulses, the enhancing effect sustains almost at any length of a linear portion of the pipeline. Attenuation of tube waves occurs very slowly. Ideally, at a distance, for example, of 200 km from the source of the wave parameters are generated virtually unchanged. The concept of dislocation of SWELT generators on linear part of a pipeline is shown in the *figure 2.*

When planning specific operation of pumping viscous or ultra-viscous oil via pipeline it is important to accurately measure and input all the specifics of the actual conditions of

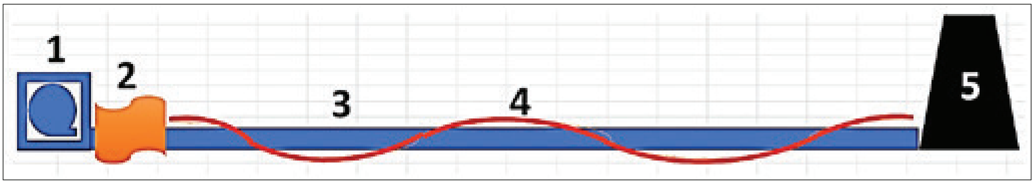


Figure 2 – **Principal diagram of SWELT on a linear section of a pipeline**
1 – booster station; – 2 – SWELT – wave generator; 3 – pipeline; 4 – generated wave; 5 – collection reservoir
(SWELT issuppliedinaway of an original pipe joint 1,2м in length, equipped with the generation assembly. Powerrequirement 1,2kWt)

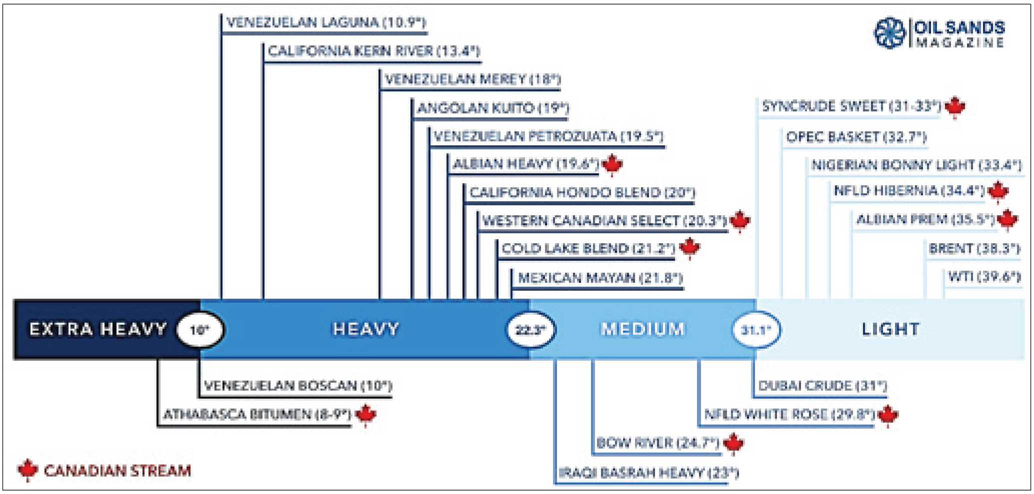


Figure 3 – **Diagram of most commonly produced sorts of crude oil. Does not include LTO (shale) extra light crude of Permian, Eagle Ford and other shale basins**

the pipeline, its path, parameters and specifications of the oil pumped *(figure 3)*, design the location of wave generators, shapes and specs of the generated waves into the modelling algorithm in order to achieve the maximum economic result. When working with existing pipelines, it is necessary to install the SWELT generators directly at the beginning of each line of the plot after each booster stations or angular intersections if the installation of linear bypasses around such stations or angular intersections is not possible.

Effect of SWELT based enhancement of transportation of viscous and ultra-viscous oil increases with increasing length of linear sections. Obstacles on a wave activated sections of pipeline, such as booster stations and angular intersections, eliminates the result of wave activation and reduces the effectiveness of transportation. As noted above, attenuation of tube waves (in the absence of sharp (30° or more) turns and changes in its section of the pipeline) is very slow. If such obstacles exist, they need to be bypassed to increase the maximum length of a linear section. The technical plan for application of SWELT shall consider and address the specific recommendations on modifying the pipeline in order to achieve the maximum economic effect.

For specific cases, such as, for instance, the Trans Mountain Pipeline (TMX) in Canada, a small field pilot would demonstrate the feasibility and efficiency of SWELT. Multiplication of volume of oil transported through the pipeline that's already in place would come as visual result of the trial. That would prove the case of achieving the goal of increasing the throughput capacity transporting heavy crude from the current 300K bpd to the targeted 890K bpd without actually having to expand on the pipeline. That would resolve huge controversy between the PM Trudeau's declared commitment to the environment and the national interest of Canada the TMX presents. The pipeline, which is now 100% owned by the Canadian Government, when (or if) it is built on schedule, will only become operational in 2022. It is quite unsure, however, that the project is going to be executed as scheduled. It seems that political, legal, regulatory and environmental impediments are insurmountable and will eventually block the execution of the TMX expansion. Goldman Sachs, for instance, is not factoring the project into its base-case forecast. Whereas with the SWELT option the higher volume of oil could be pumped through the current pipeline in this, the 2019, year and save billions of $US dollars in construction cost. Such an outstanding result could be achieved at absolutely zero environmental impact, would come in compliance with the Law and regulations, satisfy the political demands, unblock investments into development of oil production operations.

This rational is, of course, not limited to the TMX, but is also applicable to the Keystone XL and any other similar pipelines facing these challenges.

GALEX, in the way of a specialized company, provides services of SWELT enhancement of a pipeline oil transportation on agreed terms. GALEX guarantees the achievement of the effect of the SWELT enhancement in ranges defined upon assessing feasibility of the project.

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