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# Review of Spray-on or Grouting Sealants for Petroleum Product Storage Areas and Dykes in the North

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# REVIEW OF SPRAY-ON OR GROUTING SEALANTS FOR PETROLEUM PRODUCT STORAGE AREAS AND DYKES IN THE NORTH

Acres Consulting Services Limited
Niagara Falls, Canada

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## REVIEW NOTICE

## FOREWARD

Acres Consulting Services Limited performed the study as described in this report under contract Number KE204-5-EP55 to the Environmental Emergency Branch, Environmental Protection Service. Dr. D.E. Thornton of the Environmental Emergency Branch, Edmonton, Alberta, acted as Scientific Liaison Officer for this study.

**ABSTRACT**

A study was performed to investigate the applicability of sealant or grouting-sealant materials to render containment dykes around petroleum storage facilities in the North impermeable. This study included a review of the available knowledge on these materials. The materials were considered in terms of their applicability to the sealing of petroleum storage facilities, their behavior with respect to the environmental conditions expected and their ability to perform over a period of time in the Arctic. The sealants evaluated include· alkyd resins, coal tars as asphaltic products, bentonite, epoxy coatings, Gunite, polyvinyl products, rubbers, silicones, sulphur compounds, and urethanes. Of the products examined, four were judged to be potentially useful and field tests using these materials are recommended. These products are. bentonites (Volclay TFS 80), polyvinyl products, sulphur compounds (thermoplastic molten sulphur) and urethanes (in combination with a base material). Several grouting sealants were also examined including Geoseal, AM-9, and TAACS. It was concluded that grouting sealants are not suitable for the thorough sealing of a typical petroleum product storage area in the North, although these materials may have application in sealing the area beneath an existing tank.

**RÉSUMÉ**

On a réalisé une étude sur la possibilité d'utilizer des agents d'étanchéité ou des coulis dans les murs de sécurité entourant les réservoirs de pétrole dans le Nord À cette occasion, on a fait l'examen des connaissances acquises en ce domaine. Les matériaux ont été étudiés du point de vue de leur applicabilité, de leur comportement dans les conditions ambiantes prévues et de leur durée de vie utile dans l'Arctique. Les agents d'étanchéité examinés comprenaient des résines alkydes, des goudrons de houille comme les produits d'adphalte, la bentonite, de revêtements de résines époxydes, la gunite, des produits polyvinyliques, des élastomères, des dilicones, des composés du soufre et des uréthanes; quatre (la bentonite (Volclay TFS 80), les polyvinyliques, les composés du soufre (soufre fondu thermoplastique) et les uréthanes (combinés à un matérial de base)) ont été jugés utiles, et on a recommandé de les mettre à l'essai sur le terrain On a également étudié plusieurs coulis comme le Geoseal, l'AM-9 et le TAACS, mais il a été conclu qu'ils ne convenaient pas au but proposé; cependant, ils pourraient avoir des applications dans le scellement de la zone située en-dessous d'un réservoir existant.

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## 1 INTRODUCTION

The development of the Canadian North has resulted in the need for many petroleum product storage facilities of varying sizes. Permafrost has a major effect on the foundation conditions for such storage areas and the suitability of fine-grained borrow materials used to construct containment dykes. In most areas, the only borrow materials which are available and can be used in embankments are pervious sands and gravels. In some existing installations, impervious liners of various materials have been used, but many storage areas exist which are not capable of containment should a spill occur. Concern over this problem has developed in recent years within government agencies and industry.

In 1974, Imperial Oil Limited carried out a survey of petroleum spill containment dykes for Environment Canada. This study was described in Report EPS 3-EE-74-1 (by the Environmental Protection Service) dated September 1974 and entitled "Review of Petroleum Spill Containment Dykes in the North". The report contains a review of current practice and outlines the background of the spill containment problem.

A number of petroleum product spills have occurred in the past 5 years, and it appears that many of them have not been fully contained. The lack of containment has been due, in some cases, to the relatively high permeability of the storage area foundation and surrounding dykes.

At the present time, there are no widely recognized standards for dyking of petroleum product storage areas in the Arctic. However, it is agreed by government and industry that standards dealing with the impermeability requirements of storage facility dykes and foundation should be developed.

Methods of making the areas impervious are being considered by various agencies or groups. This report presents a review of potential spray-on and grouting sealants. These methods would be particularly useful for application to existing facilities where the installation of a liner, after the tank and piping facilities are in place, would be extremely difficult. The spray-on technique could also be used on new sites and possibly in combination with sheet liners.

## 2 STUDY PROGRAM

This review considers the following parameters: the chemicals and materials involved; potential environmental side effects; amounts required for application; ease of handling; material costs; size, weight, transportability and availability of equipment; ease of operation and cost of equipment; temperature and soil-type constraints; manpower requirements; application rates and coating dimensions; auxiliary protective measures and application costs; compressive strength, flexibility, weathering, resistance to petroleum products and water; freeze-thaw behavior, flammability and ease of maintenance.

A literature search of technical publications, using in-house and external facilities, was performed. Much of the information was obtained from Acres libraries in conjunction with interlibrary loans from the University of Toronto, University of Alberta, and the National Research Council. Complete lists of sources investigated and catalogues searched are presented in Appendices A and B, respectively.

A computer-aided search was conducted by the Reference and Research Science Information Services in Ottawa (NRC) of several of the sources listed in Appendix A. A summary of all the reference material is presented in Appendices C and D.

Discussions have been held with personnel from the National Research Council - Division of Building Research, American Petroleum Institute, Ontario Research Foundation, U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, U.S. Army Cold Regions Research and Engineering Laboratory, McGill Subarctic Research Laboratory, and representatives of industries as listed in Appendix E.

## 3 THE SEALANT PROBLEM - TECHNIQUES AND PRODUCTS

### 3.1 General

In considering the sealant problem, it has been assumed that a typical northern petroleum product storage area consists of a granular tank foundation pad constructed above the general grade of a relatively level area. The tank is surrounded by an earth-fill embankment, frequently constructed of sand and gravel. Foundation soils can vary from impervious silty clays to pervious sands and gravels, and are generally frozen.

It is commonly proposed that different dyking requirements for temporary and permanent product storage areas should be established. One problem with this is that temporary installations tend to drift into a state of permanency without any provisions for long-term adequacy. For the purpose of this study, temporary facilities have been considered to have a life of less than one year, and are associated primarily with drilling operations. Anything over a year would be assumed to be permanent.

In establishing adequate dyking requirements one further needs to consider the different problems associated with existing and proposed new facilities. With the former, one of the major problems involves the sealing of the area beneath the tank in such a manner as to prevent the loss of petroleum product in the event of a failure of the tank floor. Grouting of the gravel pad immediately beneath the tank has been attempted in one known case, and will be discussed in more detail in a later section. In other instances, sprayed linings have been placed inside the tank enclosure. For the rest of the storage area, spray-on or grouting sealants can be considered.

The spray-ons would cover the area from the base of the tank, over the surface of the gravel pad, across the floor of the reservoir area, and up the dyke slopes. Sealing by grout injection could involve curtain grouting (continuous vertical grout) through the surrounding dyke, and blanket grouting (continuous horizontal layer of grout) of the reservoir floor.

In proposed new installations, it would be possible to seal beneath the tank prior to placing the gravel pad. This could be accomplished either by placing a sheeted liner or using spray-on or grouting techniques in this local area. After the tank is erected and the surrounding berms constructed, the seal beneath the gravel pad could be exposed, connections made and the seal extended over the balance of the area by spray-on, grouting or even sheeted liners.

# 4 REVIEW AND ASSESSMENT OF SEALANTS

After a review of the literature and conversations with government and industry representatives, a list of potential spray-on products was selected and is presented in Table 1, together with many of their characteristics. Most of these products have been developed and have performed satisfactorily for uses other than those considered in this study. During the process of the grout investigations, primary consideration was given to the chemical grouts due to their generally low viscosity and good penetration.

The various sealant techniques and products have been assessed with regard to several environmental factors including: the effects of vapours released during and after application; the potential for the pollution of groundwater and surface water on both short and long-term bases; and the stability of the products when exposed to northern climatic conditions. Most of the sealant information was obtained from manufacturers some of whom would not provide data on the chemical constituents of their products.

## 4.1 Spray-On Sealants

For the purpose of assessing the potential spray-on products, they have been classified into groups as follows:

(a) Alkyd Resins
(b) Coal Tars and Asphaltic Products
(c) Bentonites (not spray–on)
(d) Epoxies
(e) Gunite
(f) Polyvinyl Products
(g) Rubbers
(h) Silicones
(i) Sulphur Compounds
(j) Urethanes

This is the order in which they are presented in Table 1.

The products have been analyzed, in general, on the basis of their physical and chemical properties, performance under normal and northern conditions, ease of handling, past experience and approximate costs. The potential environmental impact of these products is also discussed. A

## TABLE 1.

CHARACTERISTICS OF SPRAY-ON SEALANTS

| MATERIAL GROUP | PRODUCT TRADE NAME | PRODUCT TYPE | MANU-FACTURER | CATALOGUE OR DATA SHEET REVIEWED | MANU-FACTURER CON-TACTED | RESIST-ANCE TO PETROLEUM PRODUCTS | COLD TEMP. PERFORM-ANCE IN SERVICE | LONG TERM STABILITY OF PRO-DUCT IN SERVICE(1) | EASE OF APPLICA-TION AT LOW AIR TEMP. | EASE OF APPLICA-TION AT LOW GROUND TEMP. | FLAM-MABILITY | PREVIOUS APPLICATION IN FOLLOWING SITUATION: COLD NORTHERN | AGAINST SOIL | PETROLEUM CONTACT | COST | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALKYD RESIN | AEROSPRAY 52 BINDER | WATER-DISPERSABLE ALKYD RESIN | CYANAMID OF CANADA LTD. | YES | YES | EXCELLENT | POOR | FAIR | MUST BE ABOVE 0°C | MUST BE ABOVE 0°C | NIL | NO | YES | NO | MATERIAL 0.69/LB MOBILE ALA. (2) | |
| COAL TAR AND ASPHALTIC PRODUCTS | COLFIX JET SEAL | COAL TAR EMULSION | CHEVRON ASPHALT LTD. TORONTO | YES | YES | FAIR OR POOR | GOOD | (4) | +10°C MIN | +10°C MIN | (4) | (5) | NO | YES | (4) | NOT SUITABLE APPLIED TO SOIL. |
| | FLINTAR | COAL-TAR PITCH EMULSION | FLINTKOTE TORONTO | YES | YES | (4) | GOOD | (4) | POOR | POOR | (4) | NO | NO | YES | (4) | NOT SUITABLE APPLIED TO SOIL. |
| | KOPPER PAVEMENT SEALER | COAL-TAR PITCH EMULSION | KOPPERS CO. INC. PITTS. PA. | YES | YES | FAIR | GOOD | (4) | +10°C MIN | +10°C MIN | NIL | NO | NO | YES | (4) | NOT SUITABLE APPLIED TO SOIL. |
| | RSIK COLAS EMULSION | ASPHALTIC EMULSION | FLINTKOTE. TORONTO | YES | YES | POOR | GOOD | EXCELLENT | -4°C MIN | +4°C MIN | (4) | (4) | YES | (4) | (4) | SOLUBLE IN GASOLINE |
| BENTONITES | VOLCAY TFS-80 | SODIUM-BENTONITE BASED | AMERICAN COLLOID CO., SKOKIE, ILLINOIS | YES | YES | EXCELLENT | EXCELLENT | EXCELLENT | +0°C MIN | -0°C MIN | NIL | NO | YES | YES | $\$0.65/FT^2$ (2) | POTENTIAL PRODUCT |
| EPOXY | E.H.S. - 55 SOLVENT-FREE EPOXY COATING | EPOXY COATING | GACO PRODUCTS LTD. BRANTFORD. ONT. | YES | YES | EXCELLENT | POOR | GOOD | POOR | POOR | NIL | (5) | (4) | YES | (4) | RESISTANT TO ALIPHATICS BUT MODERATE TO AROMATIC SOLVENTS. |
| GUNITE | GUNITE (REINFORCED) | PORTLAND CEMENT COMPOUND | CONSTRUCTION COMPANY | - | - | EXCELLENT | POOR ON HEAVING GROUND | GOOD | +4°C MIN | +4°C MIN | NIL | (5) | YES | (5) | $> \$2.00/FT^2$ (3) | |
| POLYVINYL PRODUCTS | AMSCO -RES 3001 EMULSION | VINYL ACETATE POLYMER | UNION OIL CO. PALATINE. ILLINOIS | YES | YES | FAIR | GOOD | EXCELLENT | +12°C MIN | +12°C MIN | NIL | NO | YES | YES | $1.25/FT^2$ (2) | IT MAY NEED A COVER OF SOIL OF 6 TO 8 INCHES. POTENTIAL PRODUCT. |
| RUBBERS | G.P. J - 99 COMPOUND | RUBBER BASE | GACO PRODUCTS LTD. BRANTFORD | YES | YES | EXCELLENT | GOOD | (5) | +4°C MIN | +4°C MIN | (4) | NO | NO | NO | (4) | |
| SILICONES | DRI-SIL 73 WATER REPELLENT | RESIN CONCEN-TRATE WITH 60% BY WEIGHT OF ACTIVE SILICONE | DOW CORNING SILICONES (CAN.) LTD. TORONTO | YES | YES | POOR | (5) | (5) | (5) | (5) | HIGH | (5) | (5) | (5) | (5) | PERMEABLE UNDER LONG-TERM STATIC LOAD. REQUIRES LOAD. |
| | 1890 PROTECTIVE SEALER | SILIONE RUBBER | DOW CORNING SILICONES (CAN.) LTD. TORONTO | YES | YES | POOR | EXCELLENT | EXCELLENT | EXCELLENT | EXCELLENT | HIGH | NO | NO | NO | $\$6.70/LB$ (2) | REQUIRES BASE. |
| | SILASTIC 732 RTV ADHESIVE/ SEALANT | SILICONE RUBBER | DOW CORNING SILICONES (CAN.) LTD. TORONTO | YES | YES | POOR | EXCELLENT | EXCELLENT | EXCELLENT | EXCELLENT | HIGH FOR PRIMER ONLY | NO | NO | NO | $\$3.70/LB$ (2) | REQUIRES BASE. |
| SULPHUR COMPOUNDS | HYPALON | CHLORO-SULPHONATED POLYETHYLENE SEALANTS | KORZITE LTD. GUELPH AND GACO PRODUCTS LTD. | YES | YES | DEPENDS ON FORMULATION | FAIR | GOOD | +10°C MIN | -10°C MIN | NIL | YES | YES | YES | $\$1.25/FT^2$ (2) | SOME FORMULATIONS SHOW PROMISE. |
| | SPRAYED BINARY SYSTEMS | THIOKOL (POLYSULFIDE) SPRAYED OVER TUFTON SHEETING | TIBER INDUSTRIES. DELTA B.C. | YES | YES | POOR | POOR | POOR | POOR | POOR | (5) | YES | YES | YES | $\$1.25/FT^2$ (2) | |
| | SUCOAT | THERMOPLASTIC MOLTEN SULPHUR AND ORGANIC PLASTICIZER AND INORGANIC FILLER | CHEVRON CHEMICAL CO. | YES | YES | GOOD | EXCELLENT | EXCELLENT | EXCELLENT | EXCELLENT | NIL | NO | YES | YES | $\$1.75/FT^2$ (3) | POTENTIAL PRODUCT. COATING 3/8" TO 1/2", SP GR. 2.0. APPLICATION TEMP. RANGE -40°C TO 40°C. COMP. STR. 7,000 PSI. TENSILE STR. 1,400 PSI |
| URETHANES | PERMAPOL 305 | SPRAY ON BASE CLOTH | PRC CORP. WESTON, ONT. | YES | YES | GOOD | EXCELLENT | EXCELLENT | -5°C MIN | -10°C MIN | FAIR | (5) | NO | (5) | $\$1.25/FT^2$ (2) | CLOTH BASE REQUIRED. MANUFACTURER INTERESTED. FURTHER TESTING. PRICE INCLUDES BASE. POTENTIAL PRODUCT. |
| | SIKAFLEX - 1A | MOISTURE-CURED POLYURETHANE-BASE ELASTO-MERIC SEALANT | SIKA CHEMICAL LTD. POINTE CLAIRE P.Q. | YES | YES | POOR | EXCELLENT | EXCELLENT | +4°C MIN | +4°C MIN | NIL | (4) | (4) | (4) | $\$36.00/GAL$ (2) | TEMPORARY RESISTANCE (48 HOURS MAX.) NOT PRACTICAL FOR LARGE AREAS. |
| | U-WH-28 | POLYURETHANE SPRAY | GACO BRANTFORD, ONT. | YES | YES | GOOD | EXCELLENT | EXCELLENT | (4) | (4) | NIL | (4) | NO | NO | $\$1.50/FT^2$ (2) | NOT SUITABLE FOR TANK FARM CONDITIONS. |
| | ELASTUFF 504 SPRAYED OVER FILTER CLOTH | PRE-CATALYZED TWO COMPONENT ELASTOMER RUBBER | UNITED PAINT MANUFACTURING INC. | YES | YES | EXCELLENT | GOOD | GOOD | (5) | (5) | HIGH | NO | NO | NO | $\$2.50/FT^2$ (3) | OF SAME FAMILY AS ELASTUFF 701. |
| | ELASTUFF 701 SPRAYED OVER FILTER CLOTH | FLUORO COMPONENT | UNITED PAINT MANUFACTURING INC. | YES | YES | EXCELLENT | GOOD | GOOD | (5) | (5) | LOW | NO | NO | NO | $\$1.50/FT^2$ (3) | SOME PRELIMINARY TEST SPRAYING DONE BY TIBER INDUSTRIES LTD. POTENTIAL PRODUCT. |
| | URETHANE FOAM | URETHANE FOAMED IN PLACE | APPLICATORS | NO | YES | (5) | (5) | GOOD | REQUIRES FREON. GENERALLY LOWER QUALITY FOAM. | POOR | VARIES WITH DENSITY | YES | YES | NO | $\$1.00/FT^2$ (3) | UNDER STUDY BY COMINCO |

LEGEND:

(1) NO CONSIDERATION GIVEN TO COLD TEMPERATURE PERFORMANCE.
(2) COST SUPPLIED BY MANUFACTURER.
(3) COST ESTIMATED BY ACRES.
(4) INFORMATION NOT RECEIVED DURING STUDY PERIOD.
(5) UNKNOWN

questionnaire was sent to the suppliers of most of the listed products in order to obtain additional data. Information contained in the answers received during the course of the study is included in the report.

In some of the above product classification groups, there is a wide range of material types. Therefore, the individual products listed in Table 1 does not cover the complete range of available materials.

Many manufacturers and installers were understandably reluctant to provide cost and installation data for a hypothetical facility. It was necessary, therefore, to develop cost estimates based on partial information and comparisons with other products. The costs listed in the table can be considered as approximate; accurate costs can be obtained by firm bids for a specific site.

The results of the assessment of spray-on sealants are summarized below.

***4.1.1 Alkyd Resins.*** Alkyd resins are products from unsaturated polyester resins which have good properties with regard to high temperature, flammability and resistance to most hydrocarbons. The one product investigated (Aerospray 52) should not be exposed to below freezing (0 degrees C) temperatures prior to application. It is semiporous, nontoxic, does not give off harmful vapors but deteriorates under ultraviolet rays. The product is generally used as a soil and rock surface stabilizer. Because of its permeability and low strength, it is not considered to be a promising sealant for Northern application.

***4.1.2 Coal Tars and Asphaltic Products.*** Coal tars and asphaltic emulsions (liquid combinations of asphalt or coal tars with water and emulsifying agents) contain some bitumen which, in general, is soluble in petroleum products.

These products require warm temperatures for evaporation of the water solvent. The curing time, therefore, can be relatively long under adverse climatic conditions. Freezing before application or during curing will adversely affect the material. They must be sprayed onto a clean base, such as Portland cement concrete, asphaltic concrete or a filter cloth, and cannot be placed on slopes. Phenolic and carcinogenic compounds can be leached from the materials during and after curing.

Because of the above properties of these materials, they are not considered to have potential as sealants in the North.

***4.1.3 Bentonites.*** Bentonite products, in general, are not spray-ons but they appear to have potential and are therefore included in this study. They contain expansive clays which hydrate in the presence of water, creating an expanding impervious gel with good plasticity. Volclay TFS-80 has been formulated for use in sealing spill containment dykes. The distributor indicated that Volclay TFS-80 is effective in retaining petroleum products, if kept moist. The price is $0.65 per square foot installed in Edmonton. The material is basically inert, imparts no vapours during or after application, and no substances detrimental to the environment are leached from it.

The bentonites are usually mixed with the soil, using standard construction equipment, and require protection by a soil layer varying between 4 inches and 6 inches in thickness.

Volclay TSF-80 appears to be very promising with regard to cost and effectiveness. Disadvantages observed are as follows:

(a) Hydration of the bentonite by means of sprinkling water or saturation in water for a period of 7 days is required to develop the impervious gel. The water must not have a high concentration of dissolved salts.

(b) The application of bentonite for remote storage areas may be a problem since mobilization of equipment may be costly. It would require vehicles to haul the cover soil together with mixing, spreading and compaction equipment.

(c) Protection with a soil cover is required, not only to prevent damage from traffic but also to provide a cover of material to prevent or reduce dehydration of the gel in dry weather conditions. Dehydration, particularly in the dyke wall, could prove a major drawback in the Arctic because of the low annual precipitation.

(d) Flatter than normal dyke slopes, of the order of 3H:1V, are required.

Volclay TSF-80 is a promising sealant and should be subjected to laboratory and field testing.

***4.1.4 Epoxy Coating.*** Epoxy coatings are resins that, combined with a proper curing agent, provide an odorless, nontoxic polymer of high resistance to dissolution by petroleum products, but are generally brittle at low temperatures. The one product investigated, EHS-55, is not suitable for application on soils. Because of their brittle nature at low temperatures, they are not considered to be promising for Northern application.

***4.1.5 Gunite.*** Gunite or fine aggregate shotcrete (sprayed mortar or concrete), sprayed over No. 9 gauge wire mesh, may be suitable in areas of minimal frost heaving. It is liable to crack due to thermal stresses and movements under loading. However, it may be feasible to seal any cracks in the gunite with a spray-on seal but this would result in a significant cost increase. The cost of the gunite alone could be of the order of $2.00 per square foot (Edmonton area).

Air and ground temperatures would have to be higher than 4 degrees C when applied. Temporarily heated enclosures could be used to extend the available construction season. Because of the many limitations and cost of reinforced gunite, it is not considered to have much potential as a sealant in the North.

***4.1.6 Polyvinyl Products.*** Vinyl solutions and vinyl acetates produce polymer films which have adequate characteristics of strength, bond, resistance to solubility by other products and freezing and thawing. They should, in general, be applied at temperatures above 10 degrees C, and must not be subjected to temperatures below 0 degrees C in storage. This reduces their applicability to northern work.

A firm of consulting engineers in Michigan, B.P. Engineering, has sealed petroleum product storage areas using polymers mixed with small quantities of cement and natural soil at a cost of approximately $1.00 per square foot. Equipment used included a rototiller and a 265-pound vibratory compactor. As the polymers used are affected by ultraviolet rays it was necessary to cover them with a soil layer 6 to 8 inches thick. Two spills of low capacity tanks (130 to 500 gallons) of gasoline and fuel oil were recovered almost completely with no damage of the polymer shell.

There may be some potential in these products, but testing would be required and application procedures developed for cold weather spraying.

***4.1.7*** ***Rubbers.*** Synthetic rubbers are combinations of vulcanized rubber with thermoplastics. These products present good characteristics of elasticity at higher temperatures, but become quite rigid at low temperatures. The one product investigated, G.P. J-99, was not suitable for application on soil. These materials do not appear to be suitable for cold weather installations.

***4.1.8*** ***Silicones.*** Silicones are materials in which organic and inorganic substances are combined directly to produce polymers which are resistant to a wide range of temperatures, but the products listed in Table 2 appear to have poor resistance to petroleum products. Dow Corning produces some fluorosilicone rubbers which are reported to be resistant to petroleum products.

The silicones reviewed are flammable, in general, and costs are relatively high in comparison with other products. Therefore, they are not recommended as potential sealants.

***4.1.9*** ***Sulphur Compounds.*** Sulphur compounds have been divided into

(a) *Chlorosulphonated Polyethylenes.* Chlorosulphonated polyethylenes are prepared by treating polyethylene with chlorine and sulphur dioxide. Hypalons are common products from this group. Some Hypalon types have moderate resistance to petroleum products and also have good flammability characteristics; however, others have poor temperature and long-term stability properties. Problems have also been experienced with expansion due to hydrocarbon attack.

The spray-on Hypalons require a very fine filter cloth as a substrate and are therefore a binary (two-component) system. The Hypalon properties vary depending on their formulation. According to one manufacturer, the material can be adjusted to suit the requirements of petroleum product storage areas and cold weather serviceability.

The Hypalon products investigated emit no harmful vapors during curing and appear to be environmentally acceptable.

Costs are estimated to be of the order of $1.25 per square foot (Edmonton area).

(b) *Epoxy Polysulphides.* Polysulphide sealants are rubbers which are cured at about +20 degrees C and are formed by combining a basic polymer with an oxidizing agent. Polysulphides are nontoxic and resistant to a wide range of solvents. Some of these materials become hard, glassy and brittle at low temperatures. They are not, therefore, suitable for use at temperatures below -10 degrees C. Thiokol (polysulphide) also appears to be attacked by petroleum products and is sensitive to ultraviolet rays and thus is not considered to be a feasible sealant.

Tiber Industries Ltd. has sprayed a test section of coal tar polysulphide over a Tufton fabric for Imperial Oil Limited. It is understood that this test indicated that the material was unsuitable for use at low temperatures.

(c) *Thermoplastic Molten Sulphur.* SUCOAT, a thermoplastic coating material, has been developed by Chevron Chemical Company (Chevron), and is currently under study by Chevron Research Company and the Sulphur Development Institute of Canada (SUDIC) in cooperation with Chevron Research Company. SUCOAT consists of 80 percent molten sulphur plus small amounts of organic plasticizers and inorganic fillers such as talc or mineral fiber.

SUCOAT is applied by spraying the molten material in place, utilizing equipment designed for the purpose by Chevron. It is understood that this application will be made available initially through Arron Industries, Calgary, Alberta, under license from Chevron. The equipment required is complex since the material must be heated, but it is compact and mobile, being mountable on trucks.

SUCOAT is resistant to all hydrocarbons within the terms of reference of this study, and is only attacked by a high concentration of aromatics. It is suitable for application at temperatures between -40 degrees C to +40 degrees C. However, the application at the lower temperatures would be impractical in any case. The material presents good compressive and tensile strength characteristics.

Two large-scale tests with the product have been completed. One was the lining of an irrigation ditch in southern Alberta and the other, erosion stabilization of a slope in the U.S.A., the former having been conducted under the supervision of SUDIC.

SUDIC has reported only very preliminary material costs and these are expected to decrease as fullscale production commences. Indications from the drainage ditch experience are that SUCOAT is less expensive than nonreinforced concrete. Based on this inference, this cost is estimated to be of the order of $1.75 per square foot. However, large-scale tests on tank farm installations are necessary to verify costs.

It is not known if the material is brittle at low temperature, and tests to determine its cold weather application characteristics, freeze-thaw performance and resistance and resistance to light traffic, are required.

From an environmental viewpoint, the only potential problem with SUCOAT is that some sulphur vapors are given off during application. However, these are minor and subsequent damage to either animal or plant life is not expected. As the rate of oxidization of the product is negligibly slow, once cured, no vapors are emitted or chemical substances given off.

Toxicity has been tested using standard bioassay techniques and results indicate it to be environmentally acceptable. This product should be considered as a potential sealant.

***4.1.10*** ***Urethanes.*** Urethanes are produced by a condensation method from the reaction of diisocyanates and active hydrogen materials. They have good abrasion resistance, moderate petroleum product resistance, flexibility at low temperatures, long-term stability and excellent elasticity. They have to be applied by spraying on a base material such as Tufton or similar filter cloth. Some products may be more suitably sprayed on a coarser cloth such as Filter X.

There is available a product known as ''Rock Binder'' produced by the 3M Company which is utilized for stabilizing granular soil surfaces. This material also shows promise as a potential base preparation for urethane spray-on applications. It is itself a polyurethane material, but is pervious.

Tiber Industries Ltd. has conducted some trials of spray-on materials for Imperial Oil Limited, one of which was a urethane. It was their conculusion that such spray-on materials should be 100 percent solids to avoid problems associated with solvents.

The following products have been reviewed as part of this study:

(a) Perma Pol 305 appears to have potential as it has moderate resistance to petroleum products, good cold temperature performance and relative ease of application. Installation requires a temperature above 12 degrees C. It is flammable and requires a cover of 4 to 6 inches of soil to protect it from light traffic. Some bitumen is included in its formulation, the effect of which should be investigated. The installation requires the use of a Model 1000 CS meter mixer. It is estimated that the installation cost in Edmonton would be of the order of $1.25 per square foot.

(b) Sikaflex 1A, according to telephone contacts, does not resist solution by petroleum products for longer than 48 hours, and is therefore unacceptable.

(c) U-WM-28 is a 100 percent solids, two-component elastomeric urethane rubber. It is resistant to hydrocarbons but was designed for internal use and is not suitable for tank farm exposures.

(d) Elastuff is the name of a family of products manufactured by United Paint Manufacturing Inc., Spokane, Washington. Of these products, the two most promising ones are Elastuff 701 and Elastuff 504. The former is a polyurethane elastomer which has a very fast set time and shows promise for application in the north. Elastuff 504 is a precatalyzed, two-component, elastomer rubber and would constitute a more expensive installation than Elastuff 701. Both materials have service temperatures to -55 degrees C. Elastuff 701 has a better flammability rating than Elastuff 504. Both materials exhibit good abrasion resistance and strength characteristics as well as resistance to petroleum products.

Installation equipment requirements include a power supply, compressor and spraying machines which are generally available. Costs for Elastuff 701 and 504 are estimated to be approximately $1.50 and $2.50 per square foot, respectively.

All of the urethane products investigated are environmentally acceptable in service. No toxic chemicals are leached from the cured product, and they are essentially unaffected by ultraviolet light. However, during application, products which are not 100 percent solids impart solvent vapours to the atmosphere and, although they are unlikely to cause significant harm, they do increase the toxicity level within the dyke area and in some cases raise the flammability risk.

(e) *Foamed Urethanes* - Urethane foams in closed cell rigid form, foamed in place, are in common use as insulators today. They can be produced in a variety of densities ranging from 0.5 to 60 pounds per cubic foot, but more commonly in the range of 2 to 20 pounds per cubic foot.

The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) has researched the material for use in expedient roads in Alaska. It is understood that Cominco Ltd. are presently carrying out tests on foamed urethane to determine its permeability and resistance to petroleum products.

Foaming can be made to occur in the polymerization sequence by adding water to react with the isocyanate, which forms carbon dioxide--the blowing agent. More recent technology uses the vaporization of fluoroplastics as the principal blowing agent. At low temperature, the foaming can be made to occur by the addition of significant quantities of dichlor difluormethane causing what is essentially mechanical foaming. It is believed that this can result in poor quality foam.

Foamed urethane might be particularly applicable where its insulation properties would be beneficial, provided the current testing by Cominco confirms its performance suitability.

Potential problems could exist in the area of cold weather application, such as cracking due to temperature drop or due to light traffic.

Equipment necessary for urethane foam insulations is available with most commercial applicators specializing in this field. A number of such contracting firms are currently operating in northern Canadian locations.

It is estimated that a 4-inch thick layer of foamed urethane would cost of the order of $1.00 per square foot in Edmonton.

## 4.2 Grouting Sealants

The following chemical grout products were investigated.

***4.2.1*** ***Geoseal.*** Geoseal is a water-soluble resin prepolymer which is activated by a catalyst plus an accelerator to give a rigid set. It is an alkaline material, and is believed to be relatively nontoxic to aquatic and terrestrial environments. The temperature of the mix water could affect the set time. After curing it can withstand exposure to cold temperatures. The resistance of this product to aromatics is unknown, but it is resistant to aliphatic compounds.

***4.2.2*** ***AM-9.*** AM-9 is a two-compound system consisting of a mixture of two organic monomers to produce a gel. The grout has a disadvantage in that it freezes at 0 degrees C. To avoid freezing during application, the manufacturer indicates that antifreeze can be added to the mixture but this will affect the set time and must be thoroughly investigated. The set time is also strongly affected by the temperature and pH of the mixing water. The penetration of AM-9 is good as it has a viscosity similar to that of water. When cured, it is acceptable environmentally.

Caution should be exercised during handling due to the presence of acrylamide, which, if ingested by humans over long periods of time, can produce disturbance of the central nervous system.

The resistance to organic solvents is reported to be good, particularly kerosenes and petroleum fractions. Performance in cold temperatures is questionable, as laboratory tests indicate that repeated freeze-thaw conditions might rupture the membrane.

***4.2.3*** ***TAACS.*** TAACS, a Japanese product, is a one-compound system which reacts with water to produce an impermeable polymer gel with good penetration characteristics. It is acceptable from an environmental standpoint. The gelatin produced, in the solidified soil, is chemically inert, and leaching of harmful compounds from the cured product does not occur. The biological toxicity of this chemical grout to animals and plants is low and not significant. Information on cold weather performance and solubility in organic compounds is, at present, unavailable but performance is expected to be comparable with that of other grouting products listed above.

***4.2.4*** ***Grouting Costs.*** Cost estimates prepared for a typical petroleum product storage area involving sand and gravel dikes indicate that the cost of sealing using grouting techniques is approximately twice that of using spray-on sealants.

***4.2.5*** ***Overall Consideration of Grout Sealant Techniques.*** On the basis of Acres experience, and opinions expressed by others contacted during the course of this study, it is believed that grouting techniques are not suitable for the thorough sealing of a typical petroleum product storage area. The reasons for this are as follows:

(a) Complete sealing by grout injection is difficult, if not impossible, even under the best field conditions. It is difficult to know when a complete seal has been attained.

(b) In order to effect a good seal, grouting in very closely spaced holes would be required.

(c) The limitation of grouting pressures due to lack of confinement would also contribute to minimal penetration and the requirement for closely spaced holes.

(d) The presence of an active permafrost zone, which varies in depth throughout the year, would make thorough sealing difficult. Even if a good seal were achieved at a time when the active zone was at its greatest thickness, repeated freezing, thawing and possible heaving would probably damage the grout zone. The low ground temperature would affect the setting time of most grouts, and it is possible that the grouts might freeze before setting.

(e) The cost of grouting treatments would be difficult to estimate prior to actual field work. Information obtained in this study indicates that the cost could be considerably greater than equivalent solutions with other products such as linings and spray-on materials.

***4.2.6 Grout Sealing Beneath an Existing Tank.*** The problem of sealing beneath an existing tank was introduced in a previous section. During discussions with a representative from Cementation Company (Canada) Limited, a case history was related in which that firm undertook a grouting program beneath an existing tank for Imperial Oil Limited at Cobourg, Ontario. The intent was to create an impermeable barrier between the tank base and the underlying pervious sand and gravel. After sealing the tank base perimeter, a fine-particle bentonite grout was injected horizontally into the contact area between the empty tank and the foundation pad. The tank was then partially filled with water to squeeze the bentonite into the foundation soil before it gelled. It is understood that the result was not completely successful, but with further testing and development of grouting techniques it may prove to have potential.

## 5 CONCLUSIONS AND RECOMMENTATIONS

### 5.1 Conclusions

Based on the information obtained during this study, the following conclusions can be made:

(a) A review of the literature, manufacturers' catalogues, and personal contacts related to spray-on sealants have failed to locate a product which has been proven to be fully capable of retaining hydrocarbons, and to be completely suitable for the geologic and climatic conditions in the North.

(b) There are some products, however, which have the potential to be acceptable. Promising sealants on which additional investigation seems warranted are:

(1) Bentonite types - Volclay TFS 80 (not a spray-on)
(2) Polyvinyl products
(3) Sulphur compounds: Thermoplastic molten sulphur (SUCOAT)
(4) Urethanes in combination with a base material (binary system), together with soil cover.

The polyvinyl products, with their higher application temperature limitations and their deterioration under ultraviolet rays, appear to have a lower potential than the other three.

(c) Field test installations are required to prove the potential of the above products.

(d) The sealant schemes which require a soil cover have an inherent problem in the disposal of petroleum-saturated soil, should a spill occur.

(e) Based on a hypothetical installation for a facility in the Edmonton area, the cost of the spray-on sealants appears to be in the range of $1 to $2 per square foot.

(f) Grouting techniques are not suitable for providing a complete seal for a typically dyked area. Presence of active permafrost layers, lack of confining pressures, and the inherent uncertainty of the effectiveness of a grouting operation are problems associated with these techniques. Furthermore, the cost of a grouted seal appears to be significantly higher than for other methods.

The one area with potential for a grouting application is the sealing beneath an existing tank.

(g) The various sealant possibilities, as they relate to temporary versus permanent, and existing versus new facilities are indicated in the chart on Figure 1. For temporary installations some of the cheaper spray-ons could be suitable. Where a soil cover is required to protect the long-term sealant from ultraviolet rays, savings could be made by deleting the soil cover for a temporary site. A petroleum-resistant bentonite could also be a solution.

On existing permanent installations the solutions appear to be a combination of a spray-on or bentonite sealant, with an internal tank floor seal or grouting under the tank base. However, it is unlikely that the latter grouting method, using present techniques, would result in complete containment of a petroleum product spill.

For new permanent sites, the seal could be achieved using either sheeted liners or spray-ons, and possibly a combination of the two if materials are used which can be effectively joined together.

There would appear to be real merit in constructing the seal in two steps:

(a) beginning with the portion beneath the gravel tanks pad, and

(b) the balance of the seal being placed after construction of the tank and berms, when there is less likelihood of its being damaged.

## 5.2 Recommendations

It is recommended that test installations be undertaken using the following sealant types.

(a) A petroleum product-resistant bentonite
(b) Thermoplastic molten sulphur (SUCOAT)
(c) A binary system using a sprayed urethane, together with a base material and soil cover.

Such tests should be designed to provide an indication of the costs, installation problems, in-service performance and the effects of vapors and leachate on the environment for these various materials.

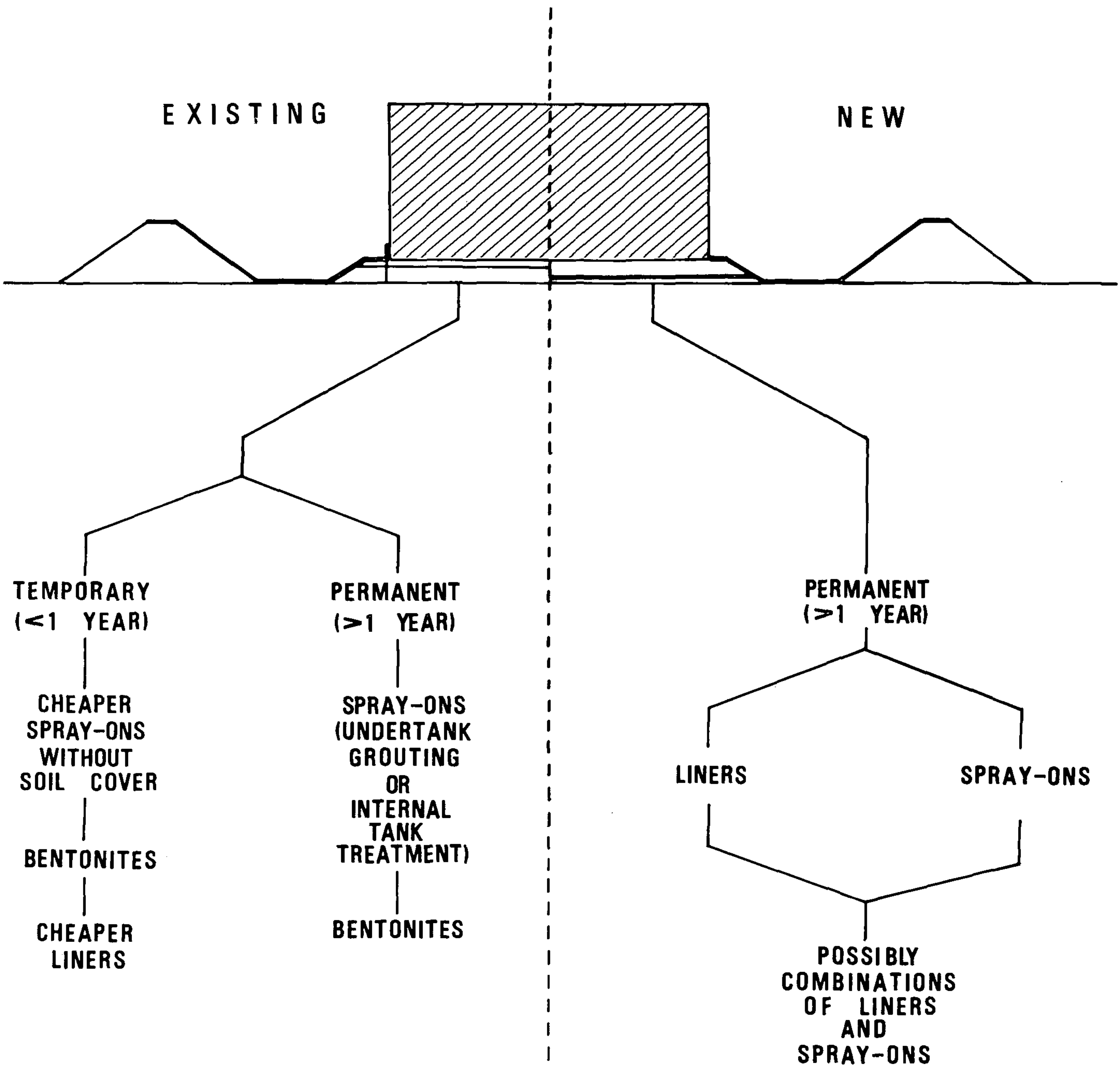


PLATE 1: SEALANT POSSIBILITIES

## APPENDIX A

## LITERATURE SEARCH - SOURCES USED

Acres Library (Papers, Periodicals, Books, Catalogues)

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American Petroleum Institute Publications and Materials, 1975

Arctic Bibliography (1970-1975)

Bibliography on Cold Regions Science and Technology (1970-1974)

Canadian Institute for Scientific and Technical Information (CISTI), NRC - Computer Search

Geomechanical Abstracts (1973)

Chemical Abstracts (1973-1975)

Geotechnical Abstracts (1970-1975)

City of Toronto - Science and Technology Library

Engineering Index (1970-1975)

Geodex (1970-1975)

Products and Manufacturers' Catalogues

Sulphur Development Institute of Canada, (SUDIC)

U.S. Government Reports Announcements (1970-1975)

U.S. Army, Cold Regions Research and Engineering Laboratories, Technical Publications, Special Report 175. June 1972 and December 1975 (bibliographies)

University of Toronto Engineering Library

University of Alberta

VSMR Microfilm Information (Acres, N.F.)

## APPENDIX B

## LIST OF CATALOGUES OR DATA SHEETS SEARCHED

American Colloid Company

Anti-Hydro Canada Limited

Atlas Chemical Industries Canada Ltd.

Borden Chemical Products

Castle Chemical Corporation

Ceilcote Canada Ltd.

Chevron Asphalt Ltd.

Chevron Chemical Company

Cyanamid of Canada Limited - Chemical Grout Technical Data

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Dupont Engineering Guide to the Dupont Synthetic Rubbers

Flintkote Company of Canada Limited

The Fabricator's Notebook - ICI America Inc.

Gates Engineering Company (GACO)

Haliburton Pressure Grouting Service

Harold Pogo Associates

Koppers International Canada Limited

Korzite Industries Limited

Lee Turzilo

Lexcan Construction Products

Master Builders

Meadows Canada Ltd.

Minnesota Mining and Manufacturing Company (3M)

PRC Chemical Corporation of Canada Limited

Sauereisen Cement Co.

Sika Chemical

Tiber Industries Ltd. (Report)

Tremco

Union Amsco (Union Oil Company of California)

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