Canada - Ontario Mineral Development Agreement

Entente Canada - Ontario sur l'exploration minérale

Canada

Ontario

MRL 85-147(COMDA) c.2

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INSITU DETERMINATION OF DEWATERED TAILINGS FILL PROPERTIES IN ONTARIO MINES

BY DOME MINES LIMITED

MRL 85-147 (COMDA)

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OF

DEWATERED TAILINGS FILL PROPERTIES

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EXECUTIVE SUMMARY

Dome Mines was awarded a contract by the Department of Supply and Services (No. 06SQ.23440-5-9204) on insitu determination of dewatered tailings fill properties in Ontario Mines. Specific objectives of the project were to develop an understanding of characteristics of fine grained dewatered tailings fill and its support potential insitu. Project tasks included assessing ground conditions for the project stope, establishing quality control systems during backfill placement, installing pressure monitoring devices to evaluate the extent of arching, conducting physical property analyses of the dewatering tailings and determining insitu bulk modulus of the cemented dewatered fill. In addition, a state-of-the-art review on dewatering schemes worldwide was to be carried out. This report presents the results of the above study.

In order to meet the above project tasks, Dome Mines selected the 755-852 Stope for monitoring. The mine has been using a Tailspinner since 1982 to place dewatered backfill into the mined out areas. The 755-852 Stope was selected because it provided an ideal opportunity to monitor insitu backfill behaviour. A series of extensometers were installed in the wall rocks of the stope to check the ground conditions and analyze the benefits of backfill as it was placed in the stope. Variations in product quality both in terms of moisture and fines contents were monitored as the dewatered backfill was placed in the stopes. The ability of the consolidated dense fill to be self supporting was examined by putting pressure cells in the mined out stope within the backfill. A series of samples were collected from boreholes by drilling into the fill and placing instruments in the boreholes. Pressure meter tests were also carried out to try to determine the insitu bulk modulus of the backfill. Finally, a state-of-the-art review on dewatering technologies worldwide was conducted on subcontract by Falconbridge Limited.

The main conclusions and recommendations as a result of the study are as follows:

1. *Paste fill technology is in its infancy in Canada but on a worldwide basis is being used extensively in Australia, South Africa and Europe. Methods for placement of paste fill include dewatering on surface or underground. For relatively low throughput rates, underground dewatering is feasible but it has the disadvantage that some of the rejected fines have to be pumped back to surface and cement, if added, has to be transported underground. Surface dewatering schemes are far more popular because they allow a larger throughput and much better control over the backfill plant. Mines in Australia, Europe and South Africa are presently using surface dewatering schemes*

with disc filters or belt filters.

2. *Underground dewatering schemes are used by Dome Mine and by Cantung Mine in Canada. Dome Mine uses a centrifuge and the Cantung Mine uses a Rake classifier. Both schemes report successful results.*

3. *Monitoring the quality of the material being placed was best achieved through regular process sampling, i.e., flow rates and density of tailings feed and correlation of this information with product moisture samples collected and dried at the dewatering site. Sampling and testing for uniaxial compressive strength provided additional data for correlation of the system performance.*

   Attempts to conduct online monitoring of product moisture proved ineffective due to the severity of the underground environment.

4. *Several instruments were installed in the backfill to monitor its insitu behaviour. The main conclusions drawn from these installations are as follows:*

   a) *There is a definite tendency for the backfill to be self supporting and to arch within the stope. Most of the earth pressure cells indicated pressure that was significantly less than the overburden pressure expected from backfill.*

   b) *There is a wide variation in insitu samples obtained in terms of void ratio, moisture content, etc. This is partly because it is difficult to obtain undisturbed samples and partly because of the gravity placement methods used for backfilling.*

   c) *Drilling in backfill proved to be extremely difficult. It was difficult to obtain samples and ultimately a continuous flight split barrel sampler was used.*

   d) *The Texam pressure meter used by Trow Ltd. on subcontract gave inconclusive results. Techniques at the present time are not available to successfully measure bulk modulus of high density fills insitu. This is due in part to the nature of the material and also due to the problems associated with preparing suitable test holes for the pressure meter.*

Follow-Up

Pastefill technologies hold tremendous potential for the Ontario mines and indeed for most mines in Canada. This fill technology is inherently safer, more cost effective and can significantly reduce the cyclical nature of mining, especially in blasthole stopes. Surface and underground dewatering schemes exist and can be used in almost any mine in Canada today. Most of the experience with these backfills is in South Africa, Australia and Europe. It is, therefore, imperative that Canadian mining industry gain experience in this field and that further research be carried out to gain further understanding of this material.

SOMMAIRE

Le ministère des Approvisionnements et Services a octroyé un contrat aux Mines Dome (No de contrat 06SQ.23440-5-9204) pour effectuer des travaux sur la détermination des propriérés in-situ des remblais denses dans les mines d'Ontario. Les objectifis spécifiques du projet étaient de mieux comprendre les caractéristiques des remblais denses à fine granulométrie ainsi que le potentiel de support en place. Les tâches reliées au projet comprenainent entre autres l'évaluation des conditions de terrain du chantier à l'étude, l'établissement des systèmes de contrôle de la qualité durant la mise en place du remblais, l'installation d'appareils de contrôle de pression pour évaluer le niveau de formation d'arche, la détermination des propriétés physiques et le module de déformation en place du remblais dense. De plus, une revue de la technologie de pointe dans les méthodes d'essorage des remblais devait également être menée, à l'échelle mondiale. Le présent rapport présente les résultats de l'étude en question.

Dans le but de pouvoir effectuer les tâches ci-avant mentionnées, les Mines Dome ont sélectionné le chantier 755-852 pour fin d'instrumentation et suivi. La mine a utilisé une centrifugeur depuis 1982 pour la mise en place de remblais dense dans les chantiers minés. Le chantier 755-852 a été sélectionné car il offrait les conditions idéales pour le suivi du comportement du remblais en place. Des séries d'extensomètres ont été installés dans les murs du chantier à l'étude dans le but de vérifier les conditions de terrain et analyser les effets du remblais lorsque mis en place dans ledit chantier. Les variations de la qualité, aussi bien au niveau du pourcentage d'humidité que de celui du contenu en fines, ont été suivies et enregistrées durant le placement du remblais dans le chantier. La capacité auto-portante du remblais dense consolidé a été examinée en plaçant des cellules de pression dans le remblais lui-même. Des séries d'échantillons ont été collectés de trous de forage effectués dans le remblais et des données ont été compilées à partir des instruments installés dans ces mêmes trous de forage. Des relevés effectués à l'aide d'un pressiomètre furent effectués dans le but de tenter de derminer le module de déformation en place du remblais. Finalement, une revue de la technologie de pointe dans le domaine de l'essorage, à l'échelle mondiale, fut menée par Falconbridge Ltée à titre de sous-contracteur.

Les recommandations, et les conclusions principales de l'étude, sont les suivantes:

1. *La technologie de la pâte de remplissage n'est qu'à ses débuts au Canada mais, à l'échelle mondiale, elle est utilisée abondamment en Australie, en Afrique du Sud et en Europe. Les*

méthodes de mise en place comprennent l'essorage en surface ou sous-terre. Dans les cas de taux de placement relativement bas, l'essorage en souterrain est rentable mais possède le désavantage qu'une certaine quantité des fines rejetées doivent être pompées à la surface et, dans le cas d'ajout de ciment, celui-ci doit être transporté sous-terre. Les différents modes d'essorage en surface sont de loin les plus populaires étant donné qu'ils permettent de manoeuvrer de plus grosses quantités de remblais ainsi qu'un meilleur contrôle des installations de remblayage. Des opérations minières d'Australie, d'Europe et d'Afrique du Sud utilisent présentement différents modes d'essorage en surface par l'utilisation de filtres à disques ou à courroies.

2. *Des procédés d'essorage en souterrain sont utilisés au Canada par les mines Dome et Cantung. La mine Dome utilise un centrifugeur et la mine Cantung quant à elle utilise un classificateur à râteau. Les deux procédés se sont avérés satisfaisants.*

3. *Le contrôle de la qualité du matériel mis en place s'est avéré plus efficace par un processus d'échantillonnage régulier, c'est-à-dire en compilant les débits et densités du remblais à l'alimentation et en faisant la corrélation avec le pourcentage d'humidité d'échantillons prélevés et séchés sur le site même d'essorage du remblais. L'échantillonnage et essai de la résistance à la compression uniaxiale a également fourni de l'information additionnelle dans l'évaluation du rendement du système.*

   Certains essais de contrôle et suivi de l'humidité du produit en circuit s'est avéré inefficace à cause des conditions environnementales en souterrain.

4. *Plusieurs instruments ont été installés dans le remblais dans le but d'étudier le comportement en place de celui-ci. Les principales conclusions tirées de l'information recueillie sont les suivantes:*

   a) *Il y a définitivement tendance pour le remblais d'être auto-portant et de former une arche en chantier. La plupart des cellules de pression ont indiqué des pressions significativement moins élevées que les pressions normales relatives à la gravité.*

   b) *Il y a une variabilité importante entre les valeurs de différents échantillons in-situ et particulièrement en ce qui concerne, l'indice des vides, le taux d'humidité et autres. Ceci est partiellement dû à la difficulté d'obtenir des échantillons intactes quant à leur intégrité physique et partiellement à cause des méthodes de placement utilisées pour le remblayage des chantiers.*

   c) *Le prélèvement d'échantillons de remblais s'est avéré quant à lui très inefficace. Il a été difficile d'obtenire des échantillons à partir de forage et ultimement on a dû utiliser un échantillonneur à baril sectionné.*

   d) *Le pressiomètre utilisé par TROW Ltée, lors du sous-contrat (Texam) a donné des résultats non concluants. Il n'existe pas présentement de techniques permettant de mesurer, de façon efficace, le module de déformation en place de remblais à haute densité. Ceci est dû en partie à la nature du matériau et en partie aux problèmes associés à la préparation de trous d'essai convenables pour l'installation d'un pressiomètre.*

SUIVI

Les technologies des remblais denses ou pâte de remplissage ont un gros potentiel dans les mines d'Ontario et certes dans la plupart des mines du Canada. Cette technologie est fondamentalement plus sécuritaire et plus rentable, et peut réduire de façon significative la nature cyclique du processus d'extraction et remblayage comme tel, et surtout dans les chantiers longs trous. Les techniques d'essorage en surface et sous-terre existent et peuvent servir actuellement dans presque toutes les opérations minières canadiennes. L'expérience partique de l'utilisation de remblais dense se retrouve particulièrement en Afrique du Sud, en Australie et en Europe. Il est donc impératif, pour l'industrie minière canadienne, d'acquérir une expertise dans ce domaine en approfondissant le niveau des connaissances de ce materiau.

ACKNOWLEDGEMENTS

This report has been completed as a joint effort by several personnel from Dome Mines Limited. The overall co-ordination and project management was provided by Mr. Dale Churcher. In addition, Dome Mines would like to acknowledge the invaluable assistance by CANMET'S scientific authority, Mr. Alfred Annor.

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APPENDICES

1.0 INTRODUCTION

Dome Mine has been involved in the development of a high density paste fill systems since 1982. A need was forecast for an increase in the production of underground backfill material to satisfy an existing backlog of open blasthole and shrinkage stopes. Regional and mine wide ground support was required as well as the release of ore reserves associated with large openings. A decision was made to utilize existing dewatering technology being used in South African gold mines and refine it for use in North America.

In 1986 Dome Mines was awarded a contract by the Department of Supply and Services on behalf of the Canada Centre for Mineral and Energy Technology (CANMET) (Contract # 06SQ.23440-5-9204) to study insitu determination of dewatered tailings fill properties in Ontario Mines. This report presents the results of this study. The work was done concurrently with second DSS contract (15SQ23440-6-9039) to study the liquefaction potential of the same dewatering tailings backfill.

1.1 Project Objectives and Tasks

The specific objectives of the project are to develop an understanding of the characteristics of fine grained, dewatered tailings fill and the benefits to the insitu properties of backfill. In addition, it is required to assess current dewatering technology worldwide and evaluate its applicability to Ontario mines.

To meet these objectives, the following specific tasks were defined by DSS:

A) Assess existing ground conditions of the project stope and provide continual monitoring with required instrumentation.

B) Establish quality control systems to ensure consistent production of dewatered fill material.

C) Install backfill pressure monitoring devices to evaluate the extent of any arching effect generated in the fill body.

D) Conduct physical property analyses on the dewatered tailings with representative samples collected from the fill stope.

E) Determine the insitu bulk modulus of cemented dewatered fill with the use of a borehole pressure meter.

F) Conduct a technical and economic feasibility study of all known dewatering schemes worldwide through a literature search and site visitations.

In order to meet the above objectives and tasks, Dome Mines initiated an extensive instrumentation program of the wall rocks and conducted a general geotechnical assessment of the ground conditions in the stope of interest. Regular samples of tailings material from the centrifuge being used for backfilling were obtained. These tailings were analyzed for moisture content, fines and general quality on a regular basis. Earth pressure cells were installed to evaluate the effects of arching in the backfill. A series of samples were collected from boreholes drilled into the fill on subcontract to Trow Ontario Limited. The samples were used to further assess the insitu properties of backfill. Pressure meter tests were also conducted to determine the insitu bulk modulus. Finally, a state-of-the-art review was carried out by Falconbridge Limited on subcontract to Dome to assess the present state-of-the-art of backfill dewatering systems worldwide.

The complete reports from Trow Ontario Limited, Falconbridge Limited and an additional subcontractor, Accurassay, are presented in the Appendices of this report. The main conclusions and recommendations from these studies carried out on subcontract are included in the main text.

2.0 BACKGROUND INFORMATION

2.1 Historical Background on Dome Mine

Dome Mine began operations in 1909 with the discovery of visible gold on a Dome shaped outcrop located West of Porcupine Lake in Northern Ontario. The orebody beneath this outcrop has supported one of Canada's premier gold mining operations for 80 years. Production during this time of over 46 million tonnes of ore has resulted in the recovery of 11.5 million ounces of gold and 2 million ounces of silver. Mining continues today at a production rate of 3500 tonnes/day with ore coming from both underground and open pit operations.

During the life of the mine different underground methods have been used to extract ore from a complex deposit consisting of single and multiple vein structures. Current fill mining was introduced in the 1930's using sandfill and later hydraulic fill for support and to provide a working platform. A total of 1.8 million tonnes of sandfill and 7.3 million tonnes of hydraulic fill have been placed underground in cut-and-fill stopes. Until the late 1960's shrinkage mining was used extensively particularly in narrow, steeply dipping zones. Bulk mining with smaller diameter longholes was introduced about this time to take advantage of low production costs. Longhole blasting has often been used to recover low grade ore from the walls or sills of old shrink stopes resulting in large open areas. Backfilling of these open holes has been restricted to smaller stopes and associated with local ground conditions.

In the late 1970's it was recognized that the number of large open holes underground which were being generated presented serious regional and local mine stability problems for future operations. In addition, economic ore reserves were being tied up in areas adjacent to multi level open stope complexes. To stabilize these stopes and allow future recovery of these ore reserves a backfilling system would be required.

2.2 Selection of Backfill Material

A typical plan and cross-section of a large open stope complex is shown in Figure 1. Several levels of the mine are exposed to this hole, with most of the intersecting drifts and raises, leading to other areas being accessible. The size and shape of this stope presents special problems for the application of backfill. It was determined that to successfully stabilize these stopes, the fill material selected must be designed with the following characteristics:

- have a high modulus to resist wall sloughage and allow a free standing exposure
- be impermeable, not allowing the buildup of hydrostatic pressure within the fill mass
- form a stable plug in drift and raise openings without the aid of fences
- be easily transported underground to remote areas of the mine
- be economic, as the cost of filling would be a direct charge

An examination of existing backfill practices suggested that high density tailings backfill would satisfy the design criteria. The product is produced by elevating full stream mill tailings to a low moisture control of 18-23% of weight, having a consistency of stiff cement mortar or tooth paste.

Other conventional backfill systems considered were eliminated for the following reasons:

HYDRAULIC FILL

Insufficient quantity available after needs of Cut and Fill operations met - Placement would require full fluid bulkheads in all openings - Poor strength gain of cemented fill due to high water to cement ratio.

WASTEROCK

Insufficient quantity available from underground development - Surface mining would be necessary at significant cost - Material handling system required to deliver rock fill to the stope at depth would be complex and costly.

ALLUVIAL SAND

Insufficient quantity of usable material available.

The advantages of using high density tailings fill are significant.

1. A high volume of mill tailings solids are recovered (up to 100%) increasing potential backfilling rates.

2. Volume of solids to be treated and compounded in surface tailings dam is reduced.

3. The water:cement ratio for paste fill is low (>4.5:1) producing greater strength gain per unit of cement added to consolidated paste fill.

4. The high angle of repose (40 degrees - 70 degrees) resulting from the stiff consistency of paste fill will form and self sealing plug in a mini opening.

5. A well graded particle size distributor is capable of generating greater compressive strength due to fewer voids.

2.3 Development of the Backfill System

In 1982 Dome Mine began a program to develop a high density fill system dedicated to residual filling of huge open stopes. The system adopted was based on a backfill dewatering centrifuge being used underground dewatering stations in South Africa. This Tailspinner centrifuge has been credited with the introduction of mill Tailings as a ground support media in the flat lying, highly stressed stopes of the South African mines.

Unlike paste fill operations where tailings are dewatered on surface using process type equipment, then pumped underground using high pressure pipelines, underground dewatering stations take advantage of conventional hydraulic transport to deliver the solids underground. Dewatering of the slurry takes place at the stope prior to placement. Excess water is contained in a pipeline for disposal.

The development program was carried out in three phases, each phase addressing specific questions to arrive at the overall objective of gaining a better understanding of the characteristics fine grained backfill and assessing the performance of the total system selected for underground production of paste backfill. The specific objectives of each test phase ore outlined as follows:

PHASE I

Set Up

- prototype equipment set up on surface adjacent to mill complex

Objective

- determine the degree of dewatering and performance characteristic typical of the centrifuge with Dome tailings

Outcome

- production of 6,000 tons of dewatered paste fill at average solids content of 78% by weight

PHASE II

Set Up

- pilot scale equipment set up on surface adjacent to open box hole into underground stope

Objectives

- operate on a continuous basis 24 hours per day, 7 days per week to determine systems operating costs resulting from wear rates maintenance
- examine the flowability of paste fill in a stope and the formation of a sealing plug in a drift opening
- conduct physical properties analysis of paste fill

Outcome

- production and placement of approximately 15,000 tons of fill in an underground stope

PHASE III

Set Up

- production installation of dewatering system underground

Objectives

- assess the performance and productivity of complete system on a pilot scale operation including materials handling of feed slurry waste return and cement powder
- conduct research on the insitu properties and performance of high density paste backfill, including the liquefaction potential of fine grained fill materials

Outcome

- production and placement of 90,000 tons of fill in an underground stope.

3.0 DEWATERING SYSTEM OPERATION

3.1 Centrifuge Performance

The ability of the backfill dewatering centrifuge to process Dome tailings into high density backfill was proven in the first phase of development. Initial concerns regarding the fineness of the tailings product affecting the fill density and recovery rate of the system were dispelled. Concentration of solids in the centrifuge underflow ranged from 76.5% to 78% by weight. This is fixed by the internal configuration of the centrifuge and physical characteristics of the fill material. Operating efficiency is measured by the percentage of input solids recovered as dense fill. To operate continuously the unit must be in an overbalanced condition with more volume of solids being fed in, than is recovered. Total recovery cannot therefore be reached. However for a continuously discharging, solid bowl centrifuge with a high concentration of feed solids, recoveries 75% - 80% were expected. The Table below summarizes typical performance parameters and recoveries measured during testing.

Backfill Centrifuge Performance	
Input Parameters	
Feed Concentration (by weight)	58% (+/- 2%)
Feed Rate - Slurry (UGGPM)	80% (+/- 15%)
Feed Rate - Solids (TPH)	18.5
Operating Speed (RPM)	1800
Output Parameters	
Underground Concentration	76.5%
Underflow Rate - Slurry (USGPM)	39
Underflow Rate - Solids (TPH)	14.3
Overflow Concentration (by weight)	32%
Overflow Rate - Slurry (USGPM)	41
Overflow Rate - Solids (TPH)	4.2
Recovery	77%

Mechanical reliability of the centrifuge was excellent. Once wear rates of initial components were established and a preventative maintenance program put into action, average availability of the unit was greater than 80%. Both the second and third phase programs were operated on a 24 hour, 7 day or 5 day schedule. The ancillary equipment, such as pumps, feeders, etc. and the mill feed supply were less reliable. However, overall utilization of 68% was considered good for a pilot scale operation.

Operation Costs

During field trials it was difficult to establish accurate operating costs due to the constant changes being made to the system and uncontrollable delays. However, some costs were fixed to establish the estimates listed below, in 1985 dollars.

High Density Fill: Estimated Operating Costs	
Labour	$1.68 Per Ton of Fill Placed
Cement	$2.25
Maintenance, Labour and Materials	$1.60
TOTAL	$5.53

Labour Costs have been calculated on a throughput of 14 TPH.

Fill Plugs

The formation of a stable fill plug in a drift opening was essential to the acceptance of high density fill at Dome. During the course of backfilling operations it was possible to closely observe the inflow of fill into drifts, draw points and a disused chute. In all cases the high density material would pour several feet out into the opening, sloping back up toward the brow. Once this point was reached, the slope would increase quickly, sealing off the opening. Final angle of repose varied from 42 degrees to 70 degrees depending on the configuration of opening being filled, moisture content and cement content of the fill being placed. For stope bottom plugs 3% cement was added. The bulk of the main pour above used 2% - 2.5% cement.

Placement

As with other fill products, the advantages of paste fill, such as low voids ratio, can be compromised if the method of introducing the fill into the stope is not given careful consideration during the design phase of a project. At Dome, gravity placement was used to advantage by discharging the fill through a 20" diameter plastic pipe into the top of the stope. The inherent stiffness of the material forming angles of up to 70 degrees, can create problems in the stope by restricting lateral distribution of fill away from the drop point. When poured, high density paste fill flows like molten lava in slow moving rivers with high shear resistance. This can result in the formation of a conical deposit beneath the drop point which, if allowed, will extend up in a steep sided cone to completely block the pipe discharge. Selection of the dewatering site must take this into consideration to allow for maximum flexibility. Flexibility can be achieved through multiple drop points, or by pumping the paste fill through pipelines or boreholes into the stope.

Pumpability

To examine the feasibility of pumping high density fill, laterally before discharging into a stope, a 45 cu.ft./hr. positive displacement concrete pump was tested at the underground site used in Phase III. Based on similar applications of pumping paste fill, a pressure drop of 2-3 psi for foot of pipe was expected. However, due to mechanical problems with the pump the tests were inconclusive. As pipeline pressures increased the seal between the pump pistons and the pipeline could not be maintained. Maximum pumping distances achieved were 150 ft. at capacities of less than 6 tons per hour.

It was felt greater distances and capacities could be achieved with a pump more suited to transporting fine solids. However, the capital and operating costs would result in significant increases in fill cost. This would not rule out the use of a positive displacement pump in other applications where the stope may b flat lying or tight fill may be required.

Cement Mixing

Cement or other binder products added to backfill for consolidation, constitute a large portion of the cost per ton of fill placed. To maximize the efficiency of the binder material not only must the water:cement ratio be kept low, the binder must be thoroughly dispersed in the fill. Because of the thixotropic consistency of paste fill and fineness of both products, it is difficult to get efficient mixing, particularly with continuous operation of the process.

A 16" diameter by 20 ft. long ribbon flight screw conveyor with adjustable back paddles was developed for the underground dewatering system to continuously mix dense fill and cement powder. It was designed to impart maximum shear in the mix and have adequate retention time. A measure of the mixing efficiency was difficult to obtain. The strength of consolidated fill samples cast underground was compared with laboratory cast samples at the same cement ratio and found to be 15% to 20% lower. It was assumed that this was primarily due to poor mixing. A reversing flight has now been attached to the main mixer/conveyor and also a double 10" diameter x 20 ft. conveyor to improve on product mix.

3.2 Production Installation

Completion of the development program and an analysis of the information and experience gained confirmed to management that a second backfill system based on dewatering tailings should be installed underground to compliment the existing hydraulic fill system.

A flowsheet of the underground backfill dewatering circuit installed on the 1100 Level at Dome is shown in Figure 2. The capacity of this system was increased from 340 tpd to 1000 tpd with the addition of two centrifuges to the original dewatering rig.

Fill Preparation

Full stream tailings from the CIP circuit are processed through a backfill thickener, to arrive at 58% solids concentration (+/-2%), for feed to the underground dewatering site. Before being sent underground the slurry is treated with $FeSO4$ to reduce cyanide levels below acceptable limits.

U/G Feed System

Two 2-1/2" diameter pipelines from the mill supply tailings underground at flow rates of 75 to 225 USGPM. The feed is contained in an 8x12 agitated storage tank before being pumped to the dewatering centrifuges. Each centrifuge is fed by a 1-1/2" x 1-1/4" glandless SRL centrifugal pump. A magnetic flowmeter monitors the pump flow rate through each line, with control being provided by a rubber pinch valve.

Dewatering Rig

Three 24" Tailspinner centrifuges are mounted on a common support structure which also houses 16" diameter by 20 ft. mixer/conveyor (figure).

Each centrifuge is driven by a variable speed hydrostatic drive. The hydraulic power packs are equipped with 50 HP electric motors and manual speed control cables, to adjust centrifuge rotational speed.

Underflow (dense fill) from the centrifuge discharges directly into the 16" diameter mixer conveyor where dry powder cement is added. It is then transferred to the double 10" screw conveyor for transport to the drop raise and into the open stope. the waste product is collected in a launder on the rig and transferred to the waste handling system via a SRL centrifugal pump.

Modular construction was used in the rig to allow ease of assembly and maintenance. Each centrifuge housing can be easily removed for maintenance and spare installed without shutting down the operation.

Cement Handling

The materials handling system to supply cement or other binder materials (usually 50/50 blend portland cement and type C flyash) must deliver up to 30 tons of product per day.

Dry powder is loaded into 2 ton (4000 litre) bulk bags from a 45 ton storage silo on surface. The bags are transported underground in box cars to the site, where they are dumped into a storage hopper. See Figure 3. this method has been successful in providing easy handling of bulk materials successful in providing easy handling of bulk materials underground. It has also proven cost effective due to the number of re-uses of the fabric bags.

Dry powder is metered from the hopper at preset rates with two vibrating tube feeders, which discharge into the mixer conveyor on the dewatering rig at average rates of 12 to 36 pounds per minute.

Waste Return

Disposal of the waste solids, lost during the dewatering process, can be handled a number of ways including: pumping back to surface as a dilute slurry; compounding underground in old workings; chemical treatment before disposal in production stope or recirculation in primary process. Due to the reasonably shallow depth of current and future dewatering operations, the decision was made to pump the material back to the mill for disposal.

Previous attempts to use staged, steel centrifugal pumps to operate a 425 psi head had failed due to the severe service the pumps were subjected to.

For the production installation on 1100 Level (1350 ft. below collar) a positive hydraulic displacement pump was selected to return the waste to surface. This pump manufactured in the United States is capable of transporting abrasive slurries at line pressures of up to 2200 psi. The system is designed to handle up to 200 USGPM through a 3"ϕ schedule 80 steel line to surface, at an operating pressure of 900 psi. A total of 307 horsepower has been installed on the pump with two air diaphragm pumps used as charge pumps. The principle of operation is based on the direct transfer of hydraulic system pressure through an isolating membrane (in this pump it is a neoprene bag) to the fluid being pumped. A series of ball check valves on the inlet, and discharge lines are the only components exposed to the slurry.

Other

Figure 4 shows a general layout of the 1100 Level installation with the major components, dewatering rig and positive displacement pump. Other support equipment such as slurry mix tanks, motor control center and a sound proof operator's booth are also indicated.

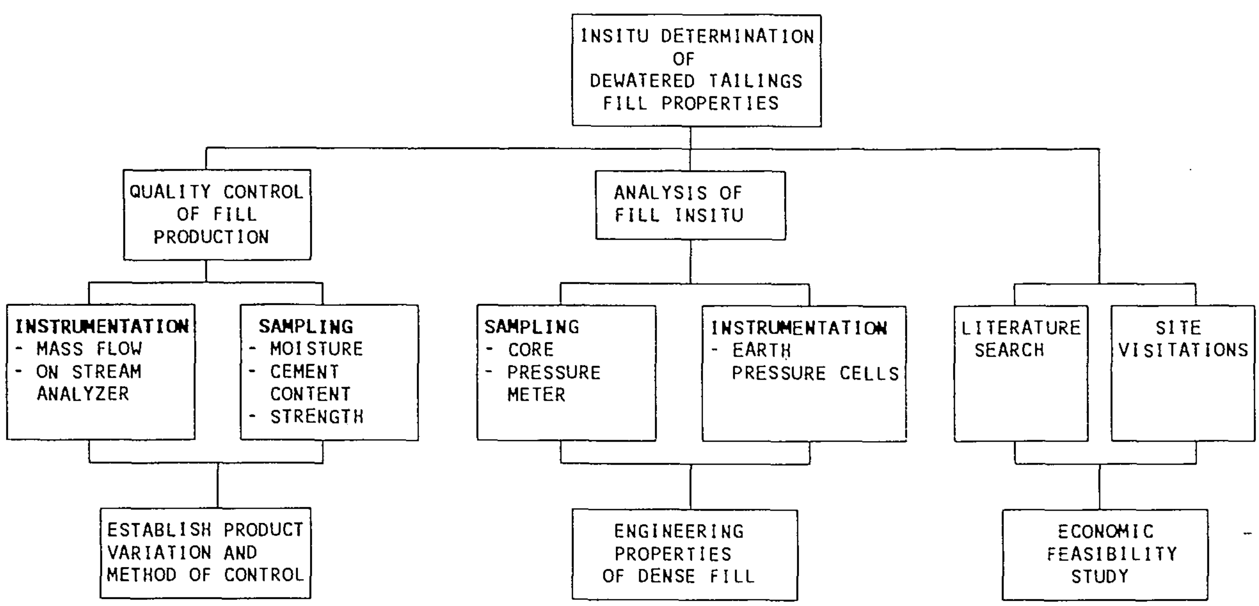
Preparations are presently in progress for the next dewatering site to be commissioned in 1989. The layout shown in Figure 5 has been kept compact to reduce development work. This will be achieved by maintaining a hydraulic displacement pump at a central location on 1100 level and operating it remotely through a Programmable Logic Controller. Future plans will consider the incorporation of the pump with the mine wide water and sludge handling systems.

4.0 PROJECT OPERATION

To execute the objectives as set out in Section 1.1, the project was separated into three main areas of effort:

1. In-situ analysis of backfill material.
2. Quality control of production and process.
3. State of the art review.

A flow diagram for the project tasks is a follows:



Work in each of the primary areas was conducted by on-site personnel during the course of backfilling operations of the test stope. Some of the work was conducted by subcontract personnel, both on-site and in the laboratory. Details of the methodology for each of the areas is described below:

4.1 In-Situ Analysis of Backfill Material

4.1.1. Instrumentation

- Install pneumatic total earth pressure cells in vertical and horizontal orientation within the main body of the backfill material. Installation procedures include inserting cells in freshly placed material adjacent to access points, preplacing cells mounted on steel framework which was then lowered into the stope from footwall access.
- Install pneumatic piezometers with each array of earth pressure cells.
- Route all pneumatic monitoring lines to central monitoring station.

4.1.2 Sampling

- Conduct core drilling of accessible backfill faces to retrieve undisturbed in-situ samples including development of reliable techniques.
- Auger drill 5" dia. horizontal hole approximately 80 - 100 ft. in depth in accessible backfill face suitable for insertion of Texam dilatometer.

4.2 Quality Control of Production Process

4.2.1 Instrumentation

- Install onstream infrared moisture analyzer to detect water content of dewatered backfill material prior to addition of cement.
- Install gamma ray density meter and magnetic flowmeter on process stream to monitor mass flowrate.

4.2.2 Sampling

- Set up facility for basic physical properties analysis of backfill material at underground dewatering site, i.e., moisture content, direct shear and compressive strength.
- Conduct regular process stream sampling, i.e., process feed material, backfill material, and waste material, for moisture content analysis to be conducted underground on site.
- Conduct regular sampling of consolidated dewatered backfill material for uniaxial

compressive strength testing, including casting and curing of all samples underground.

- Develop efficient, low cost method of monitoring cement content in consolidated backfill based on existing laboratory procedures.

4.3 State-of-the-art Review

4.3.1 Literature Search

- Conduct literature search of all Canadian and overseas mining publication facilities for information relevant to the production and placement of mine backfill at high bulk density.
- Compile gathered information for publication as state-of-the-art review.

4.3.2 Site Visitations

- Establish contact with identified users of high density backfill worldwide to assess relevance of these operations to current study.
- Conduct on-site visits to qualified users.

5.0 TEST RESULTS

In order to meet the objectives of the DSS project a series of insitu tests were carried out on the backfill and the stope being monitored to be able to assess the geotechnical characteristics of the fill and the surrounding rocks. The project stope (755-852) extends from a depth of 560 feet to 640 feet below surface (Figure 6). Due to the general conditions in the mine of the low horizontal, stress a yielding as opposed to brittle rock and the presence of adjacent mined out areas, a high level of stress build up in the walls of the stope is not likely. Any rock mass movement experienced in this stope would follow the general trend in the mine and occur in the north hangingwall resulting from the orientation of bedding planes. This occurrence would result in dynamic loading of the backfill body.

In order to study this stope and the behaviour of backfill in-situ, the following specific test program was carried out:

1. Two grouted multi-point extensometers were installed into and above a prominent wall at the midpoint of the stope length. The holes were diamond drilled and core taken from the holes was logged for geotechnical and geological purposes.

2. The input and output operating parameters of the Tailspinner dewatering system were monitored carefully to check on the quality and consistency. By monitoring both these parameters optimization of the system could be achieved through system controls. A typical set of Tailspinner operating parameters are shown on Table 1. A series of earth pressure cells were installed in the backfill to monitor the arching effect on fill. The location of these cells are shown on Figure 6.

3. A series of samples were collected from boreholes in the fill to examine various properties of the fill. Uniaxial and triaxial strength tests, void ratio, moisture content, binder content and density values were measured and compared with data from laboratory and field cast samples to correlate the effects of densification resulting from placement. The location of the boreholes is shown on Figure 7.

4. Pressure meter tests were carried out in the boreholes drilled to measure insitu bulk modulus of the backfill.

The diamond drilling, pressure meter tests, sampling of data and detailed analysis of the various strength tests and backfill properties insitu were carried out by Trow Ontario Limited on subcontract to Dome Mines Limited. Trow's report is attached in Appendix I. Location of the various instruments is shown on Figure 8.

5.1 Wall Rock Behaviour in the 755-852 Stope

As mentioned above, two extensometers were installed in the above stope to check for hangingwall behaviour as the backfill was placed. The stope remained relatively stable with some caving occurring in zones associated with near by open stopes. No creep was detected in the hanging wall or any signs of instability noted. The extensometer results therefore did not indicate any changes in movement.

5.2 Process Quality Control

Variations in the quality of the product generated by the backfill system can have a significantly adverse effect on the support capabilities of the backfill material. A program was set up to monitor the critical operating parameters of the backfill system, namely, feed collection and distribution, dewatering and binder addition.

As part of the quality control monitoring program, continuous onstream analysis of the process streams was required. To accomplish this, a mass flow system monitoring slurry density and flow rates was installed on the surface feed delivery circuit. This provided a continuous readout of the slurry flow rate, slurry density and tons/hour for the feed to the underground dewatering system. These parameters were also manually monitored by the underground operators using a magnetic flow meter and manual density scale, readings being taken at 15 minute intervals.

The dewatering process was monitored by manually sampling the input parameters and overflow density from the dewatering centrifuges. Due to the thick consistency of the dewatered backfill (underflow) a standard density scale could not be used accurately to monitor the moisture content of this product. Samples of the process streams, including underflow product, were collected on an hourly basis and checked for moisture content by weighing and drying the samples. This procedure was conducted underground at the dewatering site on an on-going basis. This method of monitoring product moisture contents proved to be the most accurate and reliable method. Attempts to automate monitoring of the backfill product density, using the infrared moisture analyzer proved unsuccessful. This was primarily due to the hostile environment, ie. dust and humidity, at the underground dewatering station.

The various operating parameters for the dewatering system, either measured or calculated, are shown in Table 2. Performance of the dewatering centrifuge proved consistent enough to rely on regular sampling of the operating parameters to maintain quality control of the backfill process.

Regular sampling was also used to monitor the quality of the consolidated backfill being placed in the stopes. Samples were cast and cured underground for uniaxial compressive strength testing on a regular basis. The results were then compared with samples cast in the lab and samples retrieved from the backfilled stope. Correlation of these results was very good, particularly between site cast and insitu samples, with laboratory cast samples showing slightly higher strengths and lower moisture contents.

Typical operating logs and performance data for the process are shown in Appendix II.

5.3 Arching in Backfill

As shown on Figure 6, a number of vertical and horizontal earth pressure cells were installed in the 755-852 Stope. The results of all these cells are presented on Figures 9 - 20.

The main conclusion from these results is that the earth pressure cells do not experience pressures in access of 5 - 6 psi. This confirms that arching did occur in the dense backfill and therefore the material was partly self supporting. If this self supporting action had not been taking place the total pressure experienced by the earth pressure cells would have been significantly higher than that noted. It should be noted that the readings were consistent between all the pressure cells.

5.4 Drilling of Backfill

Dome Mines subcontracted to Trow Ontario Limited to investigate different drilling techniques and methods for drilling of mine backfill for the purpose of sample recovery and instrumentation. A key objective of the program was to secure relatively undisturbed samples of mine fill where possible and to attempt to provide suitable test results for instrumentation. The Trow report is attached in Appendix I. The main conclusions and recommendations of this report are discussed below.

Trow used a JKS Boyles portable diamond drill supplied by DBM Technical Drilling for the shallow test holes accessed directly onto the mine fill surface. The drill was adapted for air power and provided with a gear reduction unit for rpm control. For the deeper mine fill test holes accessed through rock, a BBU-2 air powered unit supplied by Morrissette Canada Inc. was used. This unit was adapted with wire line capabilities and a hydraulic head.

A variety of rotary in-hole equipment was experimented with for the purposes of sample retrieval and instrumentation. This included the NW core barrel with various adapted casing sizes, the BW core barrel with various thin wall core bits and continuous flight augers with a modified split barrel sampler.

The following comments are made on the drilling experience gained throughout this project.

1. Relatively high degree of water content, together with the fine grained mine backfill, resulted in localized disturbance and dilatancy during drilling. Typically, with even light to moderate drill force and rotation, the mine fill has a tendency for sloughing in the immediate area of the drill hole. The retrieval of undisturbed samples is therefore virtually impossible.

2. The use of water and air for removal of mine fill cuttings during drill operation was for the most part unsuccessful.

3. Sampling with core barrels, casings and thin wall bits and with modified (serrated) casings proved to be extremely difficult. A special modified split barrel sampler had to be fabricated. The basic concept was to use a normal split barrel sampler incorporating continuous flights around the sample periphery. The flights would be aligned to provide continuity but allow easy dismantling of the sampler for sample recovery. The sampler was tested at Dome Mine and provided recovery in the range of 80% - 100%. One of the problems in the design of the sampler was its lack of penetration in dense fill.

5.5 Paste Fill Properties

Paste fill properties were determined in the laboratory by obtaining insitu samples through diamond drilling. Tests were carried out on samples prepared in the laboratory and those obtained from drilling underground. Typical fill properties, including particle sizes, moisture contents and strength values are shown on Figures 21 - 24 and Tables 3 and 4.

5.6 Pressure Meter Tests

Trow Ontario Limited attempted to undertake portions of the pressure meter testing with a Texam pressure meter after difficulties were experienced with the Probex pressure meter in the BBU-2 boreholes. The results of the testing presented by Trow in Appendix I, were inconclusive. The pressure meters tended to settle into the mine backfill during installation forcing material ahead of the probe and causing disturbance and hole blockage.

5.7 Determination of Cement Content in Backfill

Accurassay Laboratories Ltd. of Kirkland Lake, Ontario were subcontracted to look at different procedures for determining methods for estimating cement content in underground tailings backfill. Their report is attached in Appendix III.

Several different procedures were examined, including atomic absorption, spectrophotometry and titration analyses. The only reliable method found was one developed by Falconbridge Limited in 1985. This is essentially a titration procedure.

The titration method uses an ammonium chloride leach of backfill to remove the calcium from the cement and to titrate the calcium with EDTA. However, in order to measure the calcium leached from cement, blanks must be run to determine how much calcium is leached from the raw tailings and also how much calcium is present in the pure cement. To obtain accurate results for any backfill sample, a sample of the raw tailings and pure cement must be run at the same time.

A modification of the above method, developed by Accurassay, provided a similar level of accuracy in measuring the cement levels, but requires significantly less filtration time, thereby reducing the cost per analysis.

6.0 A SUMMARY OF THE STATE-OF-THE-ART REVIEW OF DEWATERING SCHEMES

Falconbridge Limited (Sudbury operations) was contracted to carry out a technical and economic review of all known dewatering schemes on a worldwide basis with specific application to Ontario mines. The main objectives of this investigation were as follows:

1. Review state-of-the-art of material dewatering techniques.
2. Compile parameters pertinent to dewatering schemes.
3. Visit mines using dewatered tailings for analysis of their approach.
4. Use a hypothetical Ontario mine as a basis of comparison for a technical economic feasibility study of different suitable dewatering schemes.

The complete report as prepared by Falconbridge Limited is attached in Appendix IV. The key points are highlighted here.

In order to carry out this study a thorough literature research on dewatering schemes worldwide was carried out. In addition, visits were made to mines in Australia, Europe, North America and South Africa to examine backfill technology first hand with specific reference to the dewatering and transport systems. A review of the different mines using a variety of backfilling technologies in South Africa is also attached in Appendix IV.

The three most common techniques for dewatering identified were:

a) Insitu drainage in a stope
b) Underground dewatering before placement in a stope
c) Surface dewatering before placement in a stope

Insitu drainage is the standard dewatering method for hydraulic fill. This involves the construction and installation of fill fences, bulkheads, etc. The lower hydration of the binding agent generally reduces strength of the consolidated fill with cement and this system generally requires an elaborate bulkhead/fence construction. In addition, large amounts of water have to be handled, backfill spills are common and curing time can be significant. Underground dewatering systems for backfill are common where relatively low production rates from backfill are required.

Two of the more common types of dewatering systems being used underground are the Tailspinner and the rake classifier. Both these machines have been used in Canadian mines. Successful results, both economic and technological, have been reported. In these instances the hydraulic fill is transported by a pipeline at a normal low density slurry (70% or less) underground. Slurry is fed into a dewatering machine and the paste-like underflow is placed in the stope without a need for further drainage. The overflow, still containing up to 30% - 40% solids, is pumped back to surface for disposal in a tailings pond.

The major disadvantage of underground dewatering machines is the low throughput (generally less than 30 tonnes/hour) the fact that the reject material has to be repumped to surface and the cement handling, if any, requires special arrangements. Dome Mine uses a Tailspinner and is a good example of an underground dewatering scheme.

Surface dewatering requires a disc or belt filter to remove the extra water from the tailings before the paste-like slurry (similar to that of a low slump of concrete) is pumped utilizing concrete pumping technology to the underground stopes. Water content in the fill is used up during hydration of portland cement and therefore no further dewatering is required. Although surface dewatering techniques can provide a high output rate (in excess of 50 - 200 tonnes/hour) this technology is more complex. The type and gradation of materials, the ratios in which these are mixed and the pumping techniques must be carefully designed to ensure optimum performance at an acceptable cost. In addition, extensive pilot plant testing is required to study fill rheology.

6.1 Conventional Backfill Dewatering

Backfilling has long been an integral part of underground mining operations. A variety of backfill materials have been used underground. This includes rockfill, alluvial sand and mill tailings. In addition, some of the more unique backfill systems have been developed, such as frozen rockfill at Cominco's Polaris Mine and the use of well graded gravel at Que River Mine in Australia. Tailings backfill is by far the most common material used at most mines, although rockfill is gaining increasing emphasis. Some of the typical properties of classified hydraulic fills are shown on Table 5.

As Table 6 indicates, strength of backfill and concrete is significantly influenced by the water to cement ratio for a given mix. The same is true for mine backfills. The higher the density at which the fill is placed the greater the strength of the backfill. There are obviously significant economics to be gained by using high density backfill in underground mines.

6.2 Fill Plants

High density backfills with surface dewatering schemes are used in a number of mines in Europe, South Africa and Australia. The most successful application of high density fills in Europe has been Preussag Grund Mine. At this mine the dense media rejects (in the range of 3 mm - 30 mm) and flotation tailings in the range of 0 mm - 0.05 mm are mixed in a 1:1 ratio dewatered and pumped as a concrete-like mixture. To avoid blockages the volume of fine material always exceeds the theoretical pore volume of the core's fraction. In addition, the consistency is regulated so as to ensure the Bingham plug flow. Cement is added underground at the discharge point.

A good example of a surface high density fill plant was noted at Elura Mine in Australia (Figure 25). This mine located some 750 km west of Sidney, Australia is a modern silver zinc mine brought into production by North Broken Hill Holdings Ltd. in the early 1980's. Backfill material is composed of crushed rock (-50 mm), filtered mill tailings, cement and water. The approximate proportions are as follows:

Crushed rock 34% by weight
Filtered tailings 51% by weight
Cement 7% by weight
Water 8% by weight

Backfill materials are mixed on surface at the fill plant into a pastelike composition and pumped into a 15 mm diameter line at the rate of 50 cu meter/hour to the underground stopes. A simplified floor sheet is shown on Figure 25. This system is highly efficient and mining against placed backfill material can begin almost immediately. The total cost however, is close to $10/tonne of backfill placed.

6.3 Conclusion

The main conclusion of the state-of-the-art review is that pastefill technology is available today for application at most mines. It is, however, in its infancy in Canada and further research is required to enhance and encourage its application at most mines. A structured approach as outlined in Figure 26 is recommended to ensure its proper application and success.

TABLE 1

TAILSPINNER OPERATING PARAMETERS

DESCRIPTION		UNIT OF MEASURE	METHOD OF MONITORING	FREQUENCY OF MONIOTORING
INPUT				
I-1	Concentration of solids in feed product	% Solids by Weight	Sample weigh and dry	Every Hour
I-2	Particle size distribution of tailings in feed product	Cumulative % Passing	Screen/Hydrometer Analysis	Every Shift
I-3	Volumn of slurry flow to the dewatering unit	Gallons/Minute	Magnetic Flow Meter	Continuous
I-4	Width of peripheral discharge gap in dewatering unit	Millimeters	Vernier Caliper	Every 160 Hours of Machine Operation
I-5	Rotational speed of dewatering	Revolutions/ Minute	Digital Tachometer	Continuous
OUTPUT				
0-1	Moisture content of dewatered product	% Moisture by Weight	Infra Red Analyzer	Continuous
0-2	Moisture content of waste product	% Moisture by Weight	Sample Weight and Dry	Every Hour
0-3	Particle size distribution in dewatered product	Cumulative % Passing	Screen/Hourmeter Analysis	Every Shift
0-4	Particle size distribution in waste product	Cumulative % Passing	Screen/Hourmeter Analysis	Every Shift
0-5	Efficiency of dewatering process	% Solids Recovered	Calculated From I-1, I-3, 0-1, 0-2	Every Hour

TABLE 2

BACKFILL CENTRIFUGE PERFORMANCE

INPUT PARAMETERS			
- Feed Concentration (by weight)			58% (± 2%)
- Feed Rate	-	Slurry (USGPM)	80 (± 15%)
	-	Solids (TPH)	18.5
- Operating Speed (RPM)			1800
OUTPUT PARAMETERS			
- Underground Concentration			76.5 %
- Underflow Rate	-	Slurry (USGPM)	39
	-	Solids (TPH)	14.3
- Overflow Concentration (by weight)			32 %
- Overflow Rate	-	Slurry (USGPM)	41 %
	-	Solids (TPH)	4.2
Recovery			77 %

TABLE 3

IN SITU PASTE BACKFILL MOISTURE CONTENT

SAMPLE NO.	DEPTH (ft.)	MOISTURE CONTENT (% dry weight)
1	0 - 1.5	22.0 %
2	1.5 - 3.0	23.1 %
3	3.0 - 4.5	19.6 %
4	4.5 - 6.0	22.1 %
5	6.0 - 7.5	20.8 %
6	7.5 - 9.0	22.7 %
7	9.0 - 10.5	21.7 %
8	10.5 - 12.0	21.0 %
9	12.0 - 13.5	19.2 %
10	13.5 - 15.0	16.8 %

N.B. Samples from augered test hole in backfilled stope.

TABLE 4

TYPICAL PROPERTIES OF PASTE BACKFILL

Youngs Modulus	9572.1 psi	(66 MPa)
Void Ratio	0.599	
Cohesion	17.44 psi	(120.3 kPa)
Friction Angle	21.8 Deg.	
Density	99.443 lb./ft^3	(1592.99 kg/m^3)
Uniaxial, Compressive Strength	62.35 psi	(429.92 (kPa)
Tailings:Cement	1:30	
Moisture Content	19.05 %	

TABLE 5

SIZE DISTRIBUTION OF SOME HYDRAULIC FILLS

	% RETAINED			
	STRATHCONA FALCONBRIDGE	FOX MINE CYCLONE U/F	FOX MINE AT STOPES	CSA MINE WESTERN HOLDING
Tyler Mesh	(Ref. 9)	(Ref. 10)	(Ref. 10)	(Ref. 11)
48	20.0	7.23	9.37	-
65	34.7	25.30	19.80	0.4
100	51.7	47.10	38.04	1.4
150	68.0	78.79	58.55	8.3
200	76.9	87.85	75.46	23.1
270	83.7	-	-	-
325	98.4	-	-	41.8
<325	100.0	-	-	-

TYPICAL HYDRAULIC BACKFILL STRENGTH PROPERTIES

SAND:CEMENT RATIO	UNIAXIAL COMPRESSIVE STRENGTH (28 days)
40:1	16-40 psi (97-276 kPa)
30:1	40-70 psi (276-483 kPa)
20:1	70-100 psi (483-689 kPa)
10:1	200 psi (1379 kPa)
5:1	500-600 psi (3447-4137 kPa)
2:1	2,500 psi (17237 >kPa)

TABLE 6

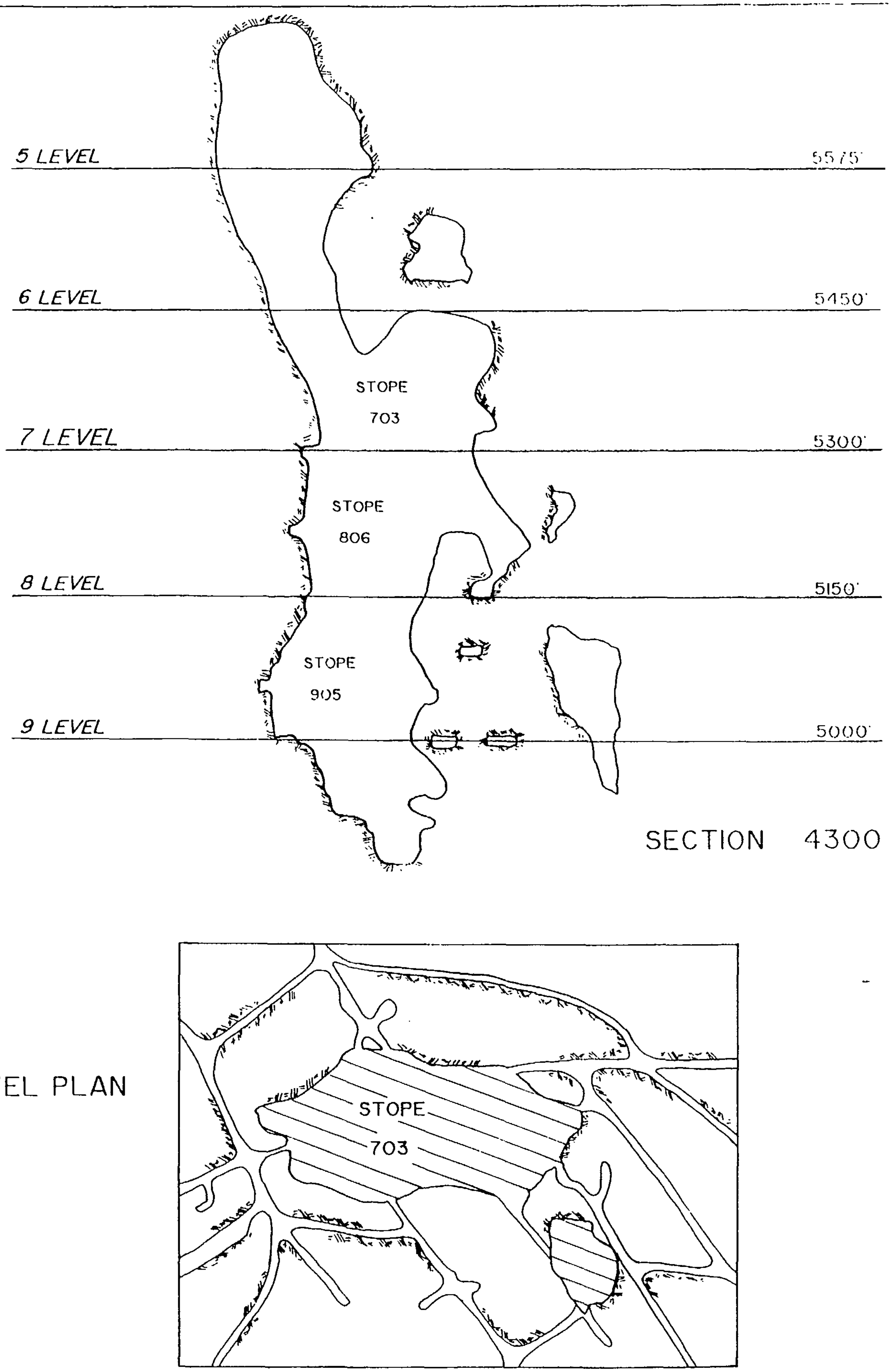
COMPRESSIVE STRENGTH OF CONCRETE

AT 28 DAYS PSI (kPa)	WATER-CEMENT RATIO BY WEIGHT (NON-AIR ENTRAINED)
6,000 (41,000)	0.41
5,000 (34,500)	0.48
4,000 (28,000)	0.57)
3,000 (21,000)	0.68
2,000 (14,000)	0.82

TYPICAL COMPRESSIVE STRENGTH OF BACKFILL

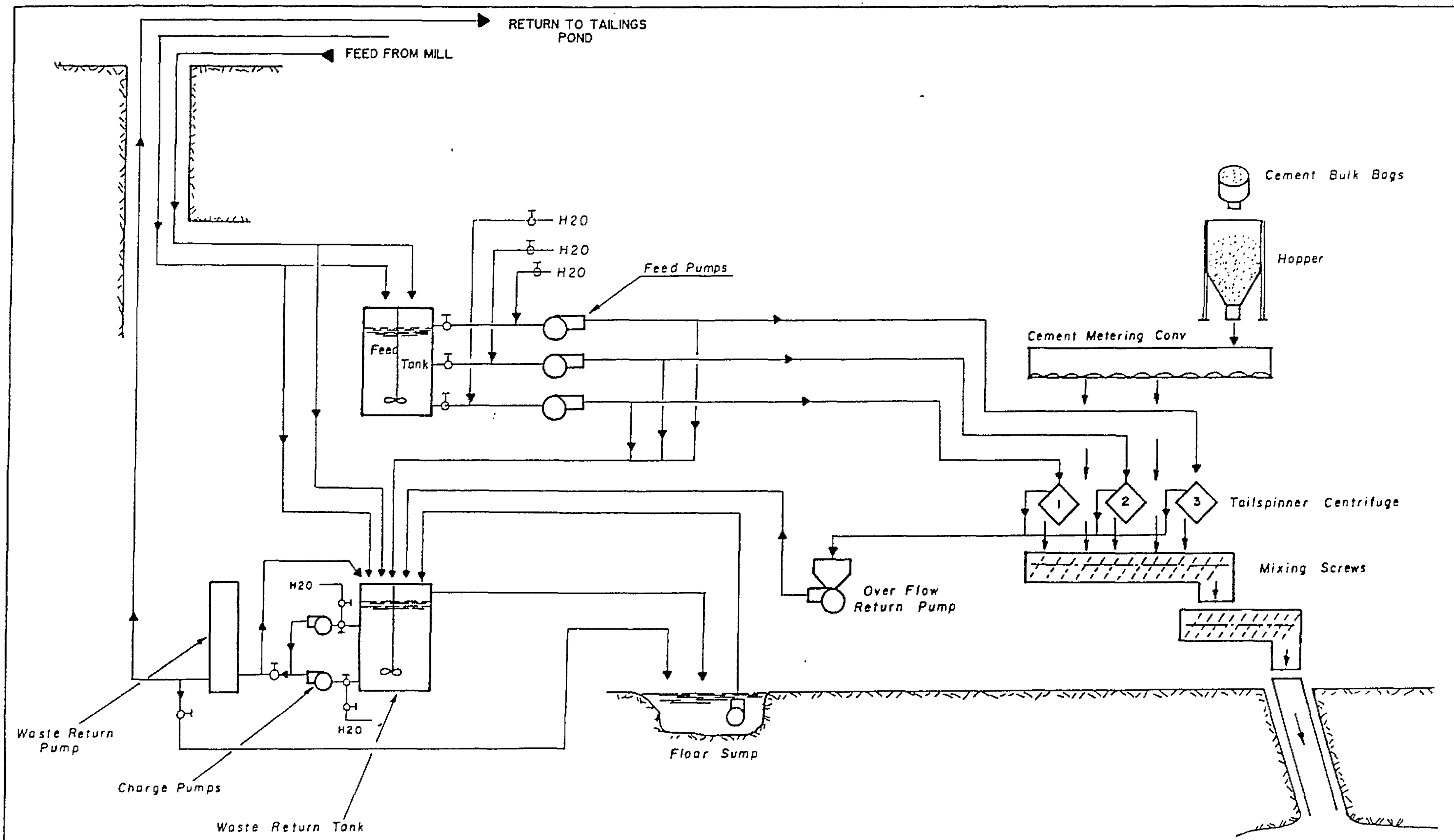
CEMENT RATIO	28 DAY STRENGTH, PSI (kPa)				
	60% SLURRY DENSITY	66% SLURRY DENSITY	72% SLURRY DENSITY	73% SLURRY DENSITY	76% SLURRY DENSITY
32:1	15 (103)	15 (103)	30 (207)		
20:1	29 (200)	34 (234)	58 (400)		
16:1					238 (1641)
13:1				99 (683)	
10:1	82 (565)	112 (772)	172 (1186)		
5:1					515 (3551)
4.5:1				490 (3378)	

FIGURES



7 LEVEL PLAN

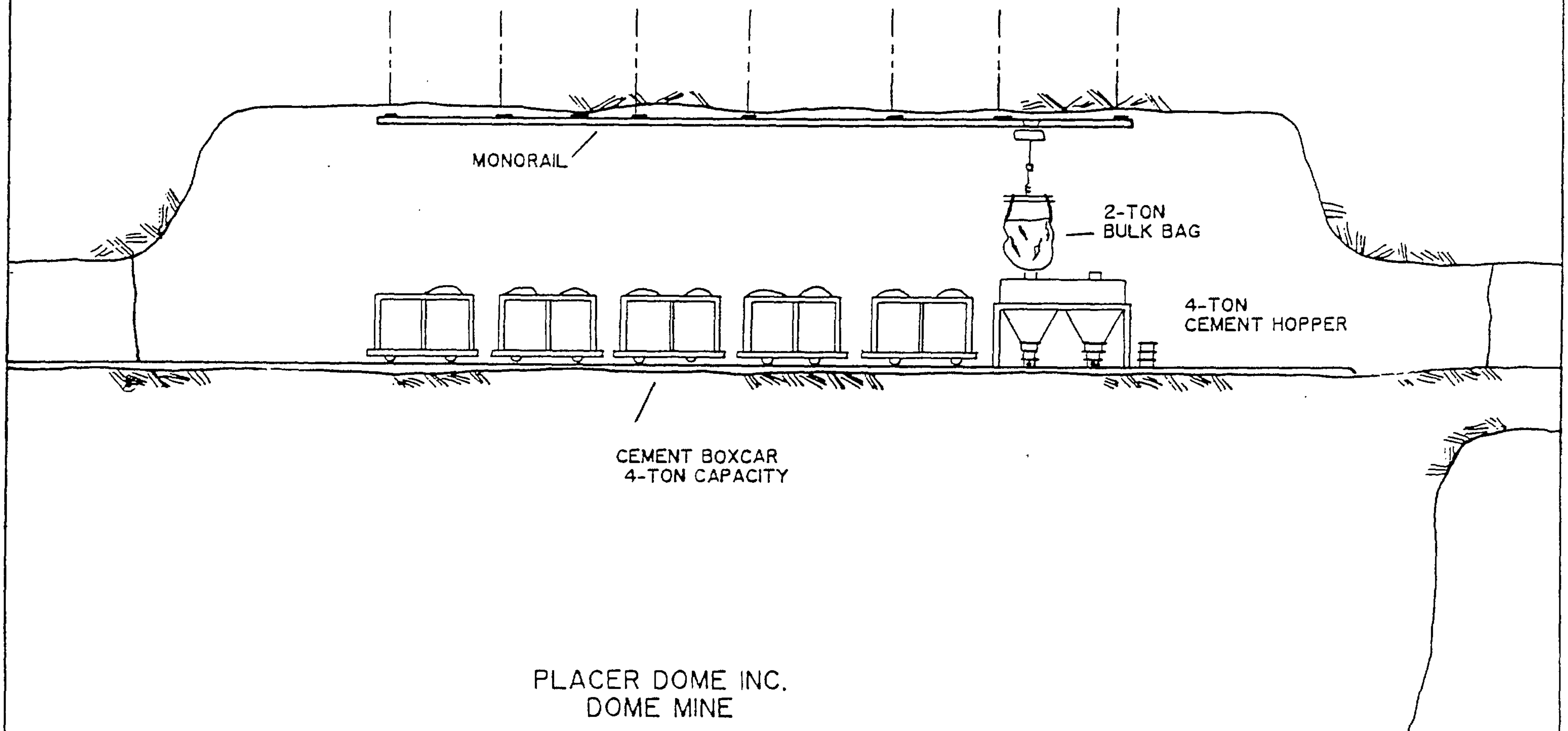
FIGURE 1 PLAN AND SECTION OF THE 905 STOPE COMPLEX



Underground Backfill Dewatering System Production Flow Sheet

PLACER DOME INC. — DOME MINE

FIGURE 2



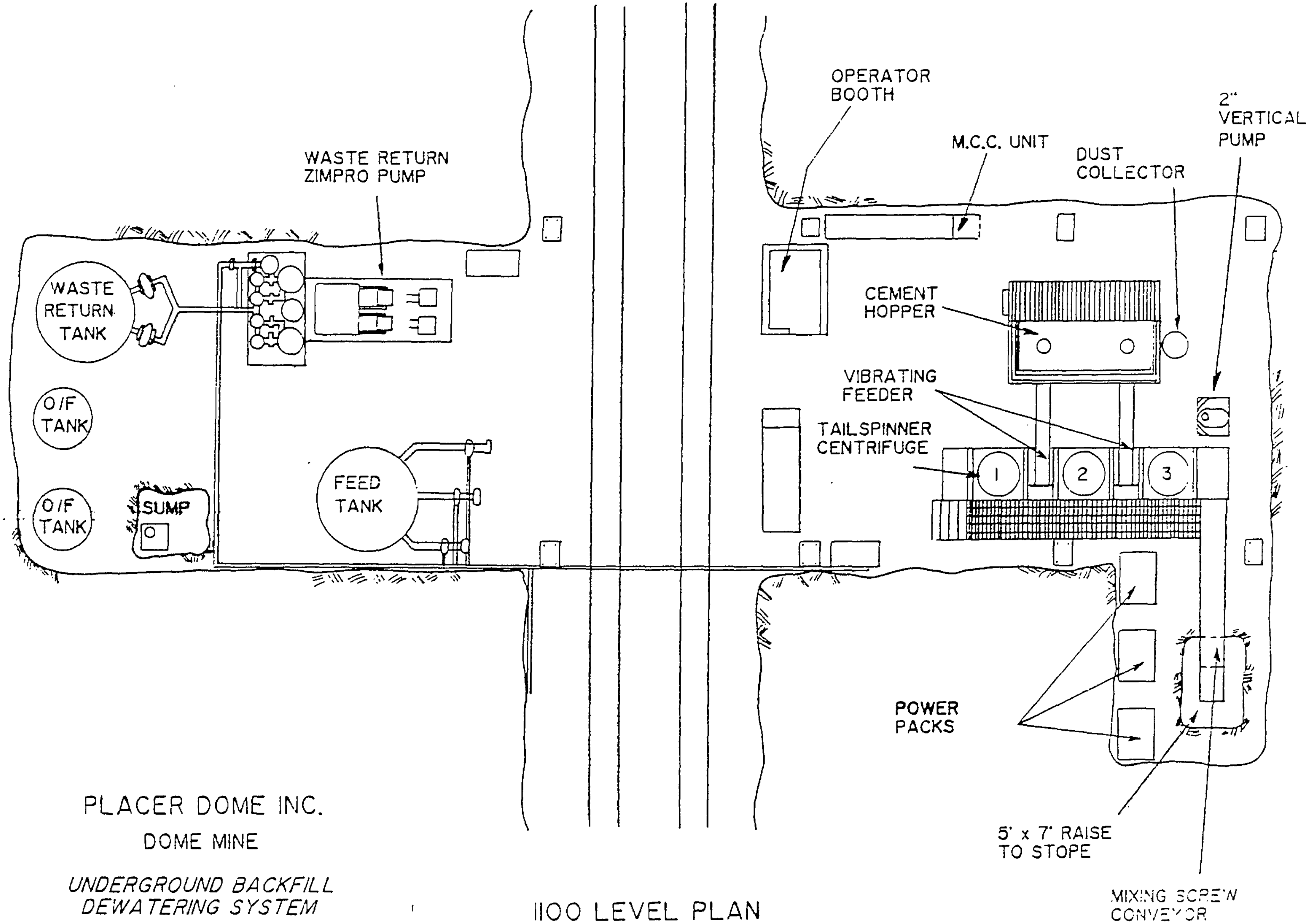
PLACER DOME INC.
DOME MINE

CEMENT HANDLING SYSTEM

CROSS-SECTION

900 LEVEL

FIGURE 3



PLACER DOME INC.

DOME MINE

UNDERGROUND BACKFILL DEWATERING SYSTEM

1100 LEVEL PLAN

FIGURE 4

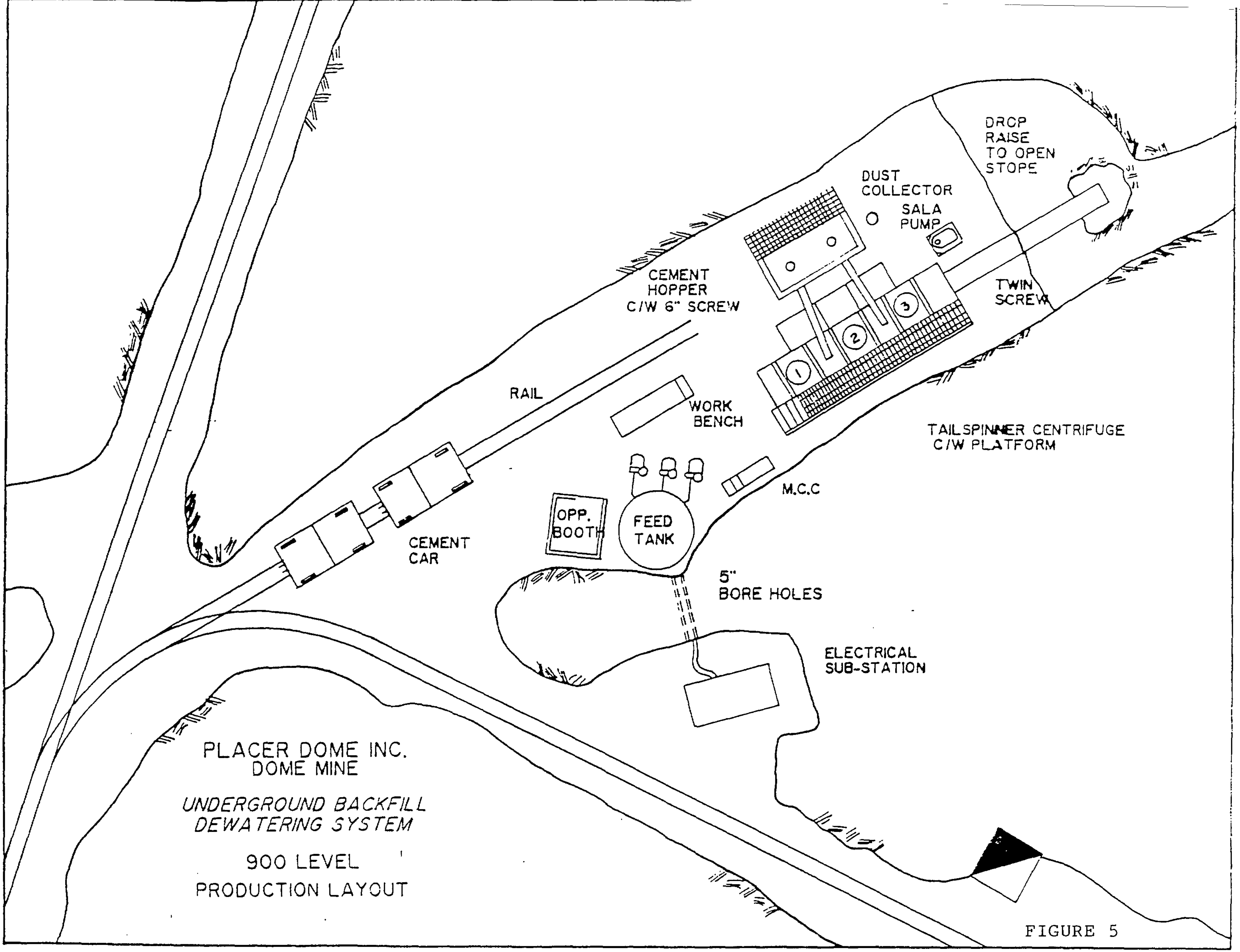

DROP
RAISE
TO OPEN
STOPE
DUST
COLLECTOR
SALA
PUMP
CEMENT
HOPPER
C/W 6" SCREW
TWIN
SCREW
RAIL
WORK
BENCH
TAILSPINNER CENTRIFUGE
C/W PLATFORM
M.C.C
OPP.
BOOTH
FEED
TANK
CEMENT
CAR
5"
BORE HOLES
ELECTRICAL
SUB-STATION
PLACER DOME INC.
DOME MINE
UNDERGROUND BACKFILL
DEWATERING SYSTEM
900 LEVEL
PRODUCTION LAYOUT

FIGURE 5

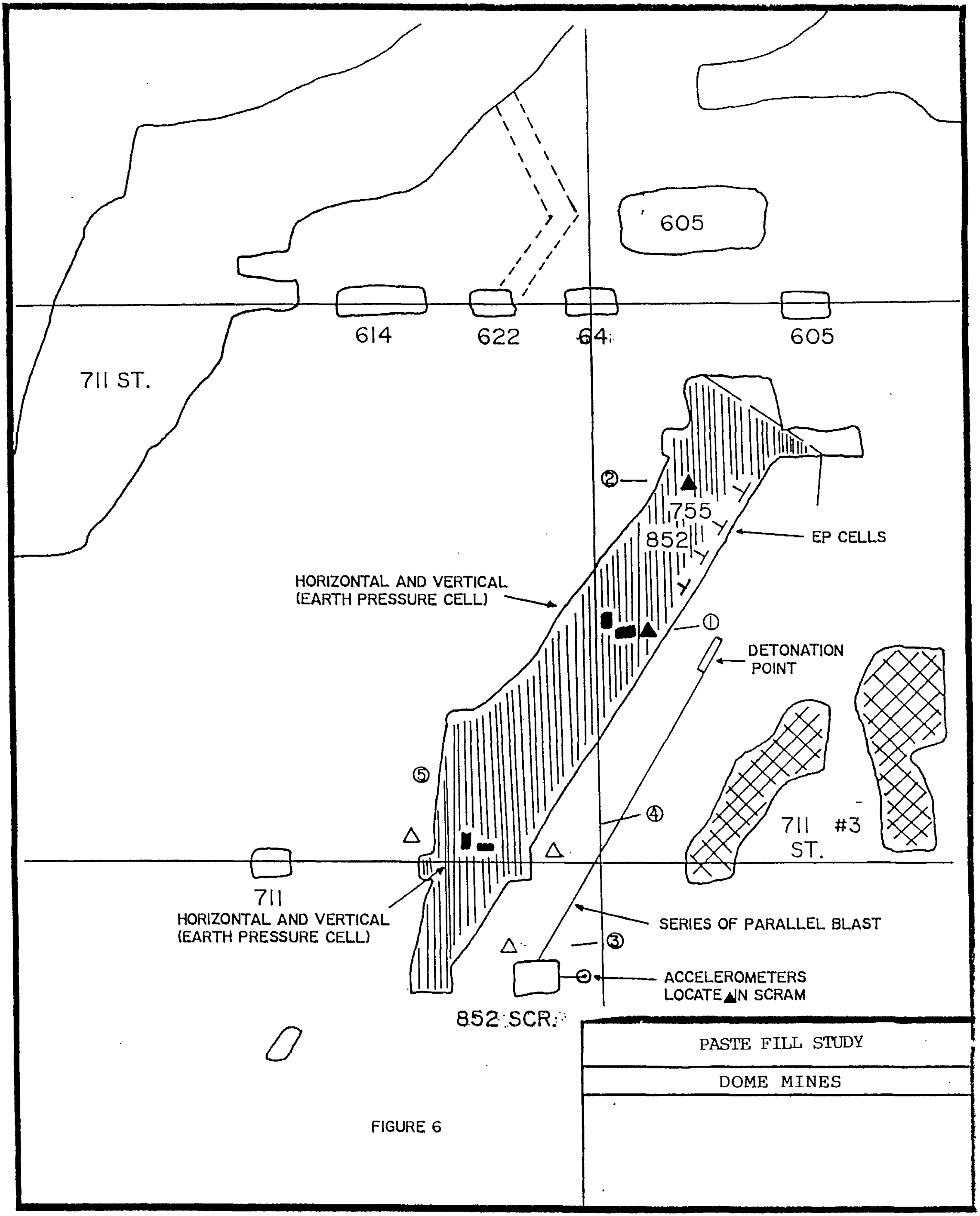

605
614
622
64
605
711 ST.
②
755
852
EP CELLS
HORIZONTAL AND VERTICAL
(EARTH PRESSURE CELL)
①
DETONATION
POINT
⑤
④
711 #3
ST.
711
HORIZONTAL AND VERTICAL
(EARTH PRESSURE CELL)
SERIES OF PARALLEL BLAST
③
ACCELEROMETERS
LOCATE IN SCRAM
852 SCR.
PASTE FILL STUDY
DOME MINES

FIGURE 6

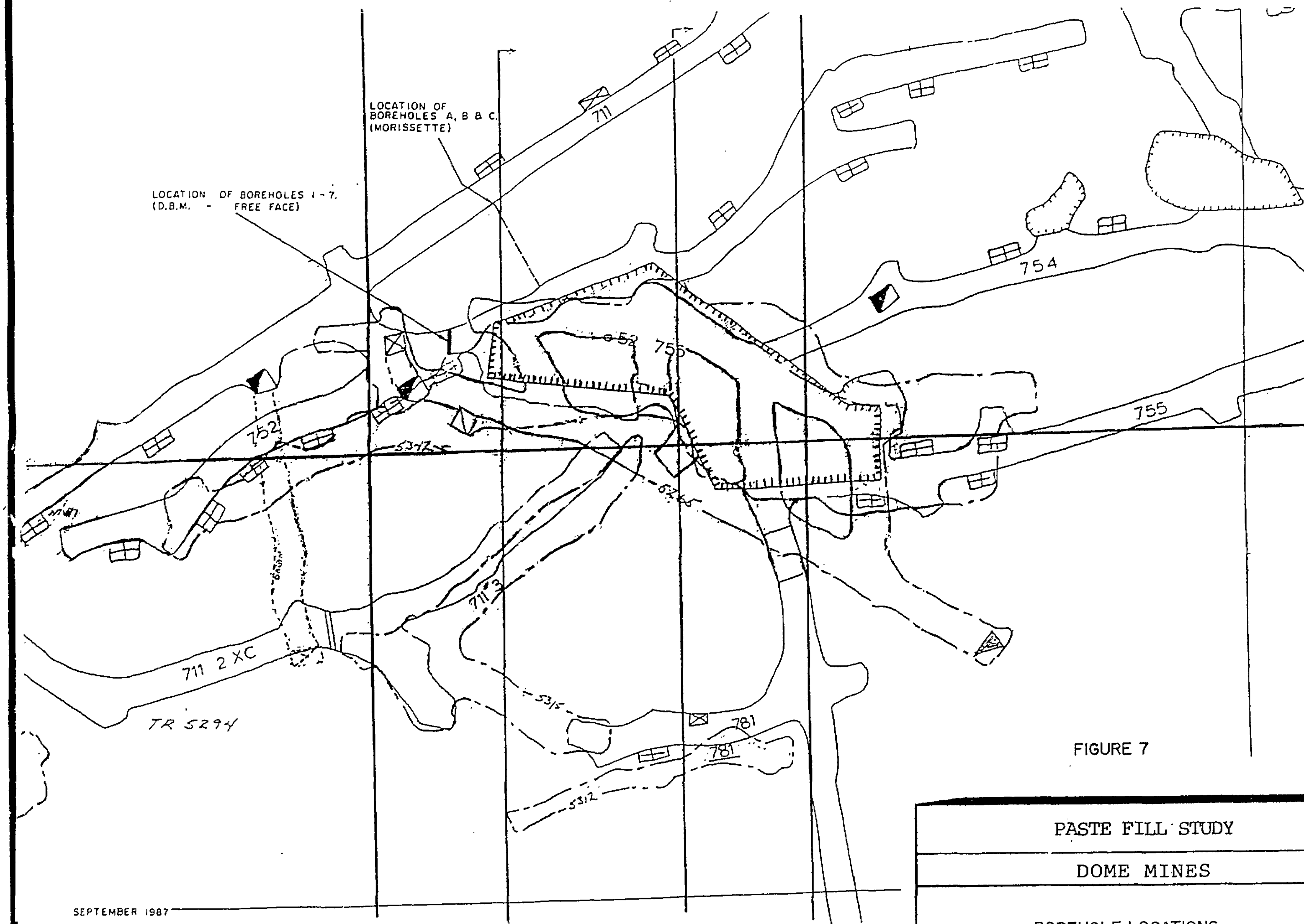


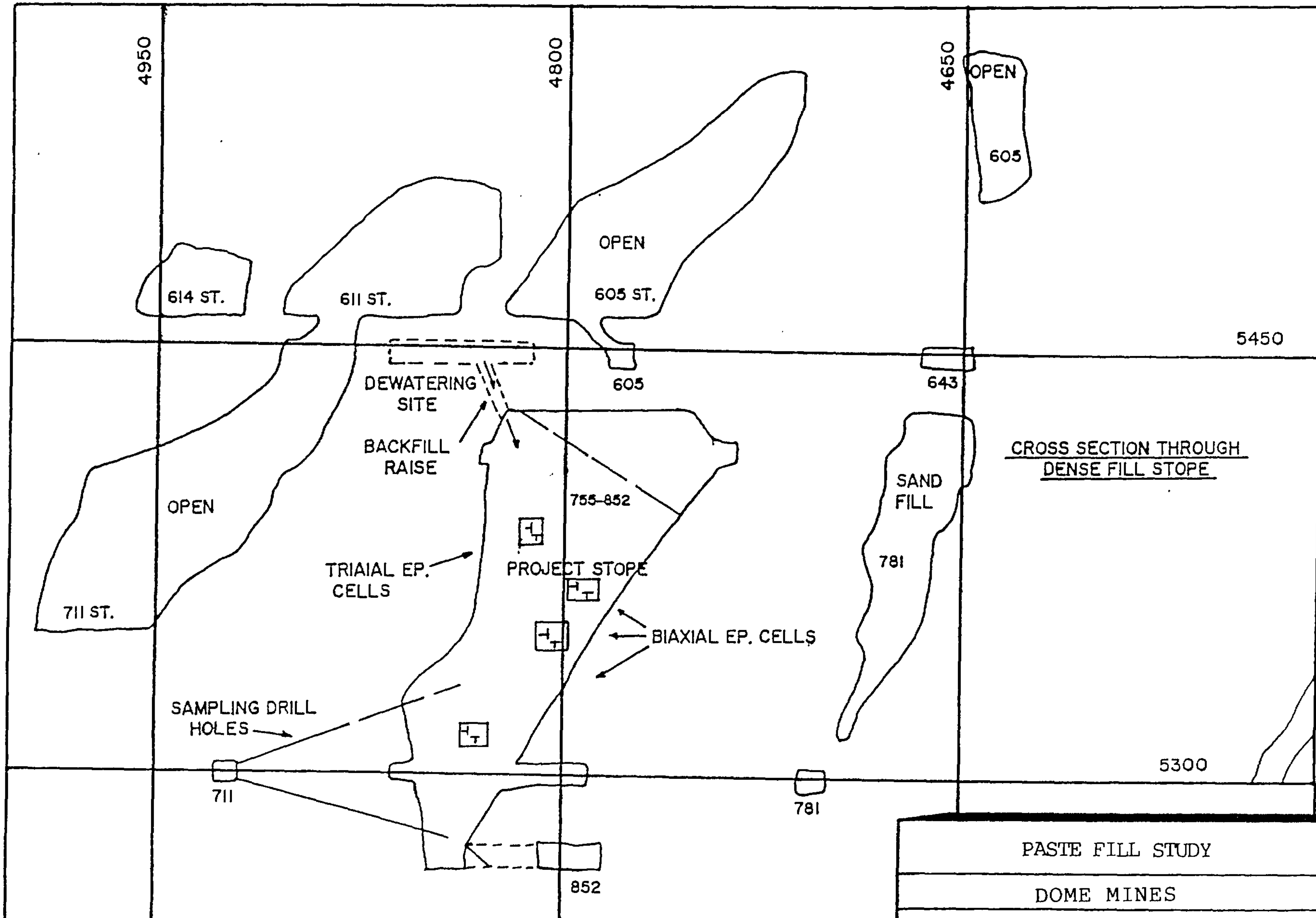
FIGURE 7

PASTE FILL STUDY

DOME MINES

BOREHOLE LOCATIONS

SCALE 1"=20'



PASTE FILL STUDY
DOME MINES
SECTION 4405

FIGURE 8

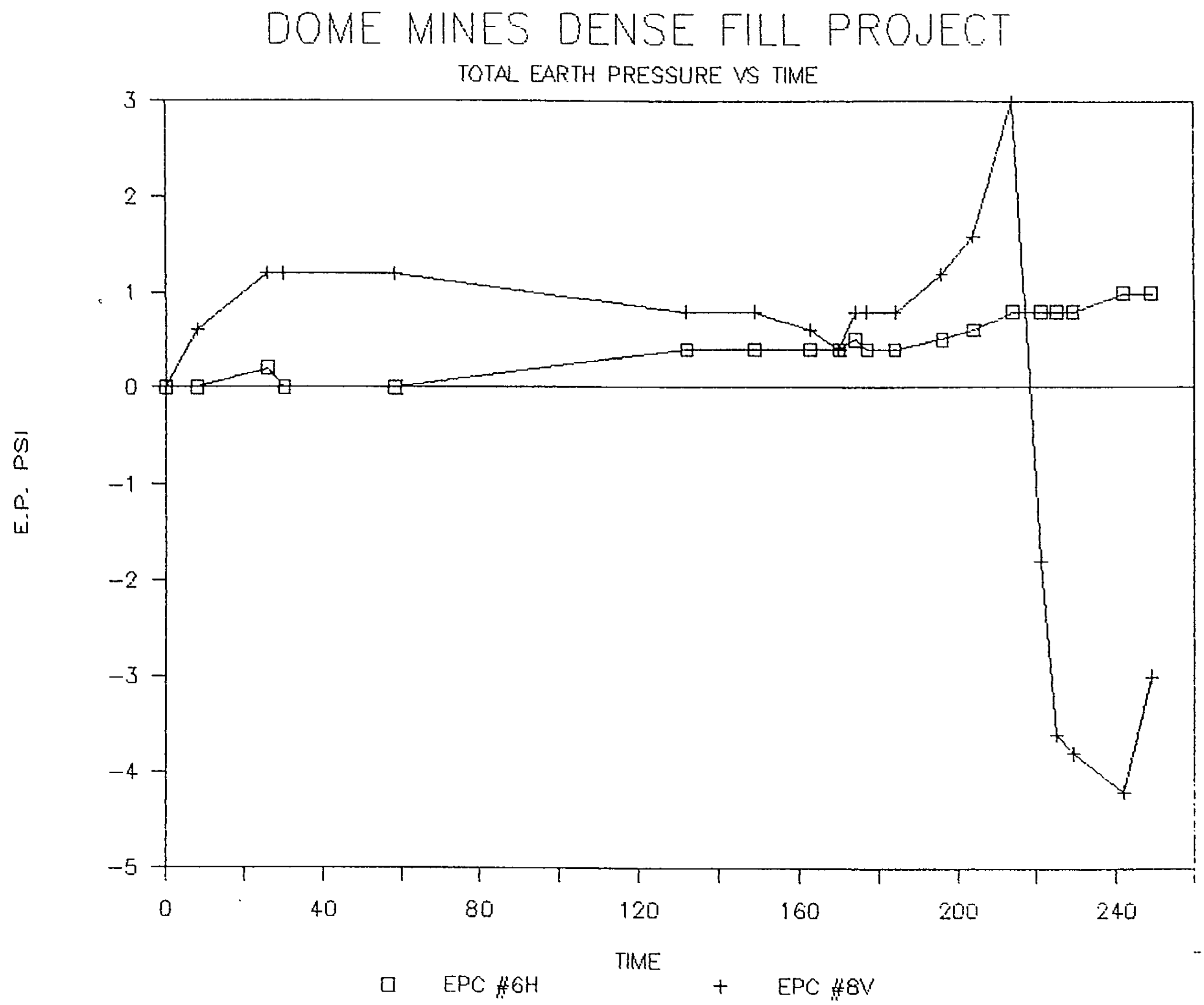


FIGURE 9

PASTE FILL STUDY
DOME MINES
TOTAL EARTH PRESSURE VS TIME CHART

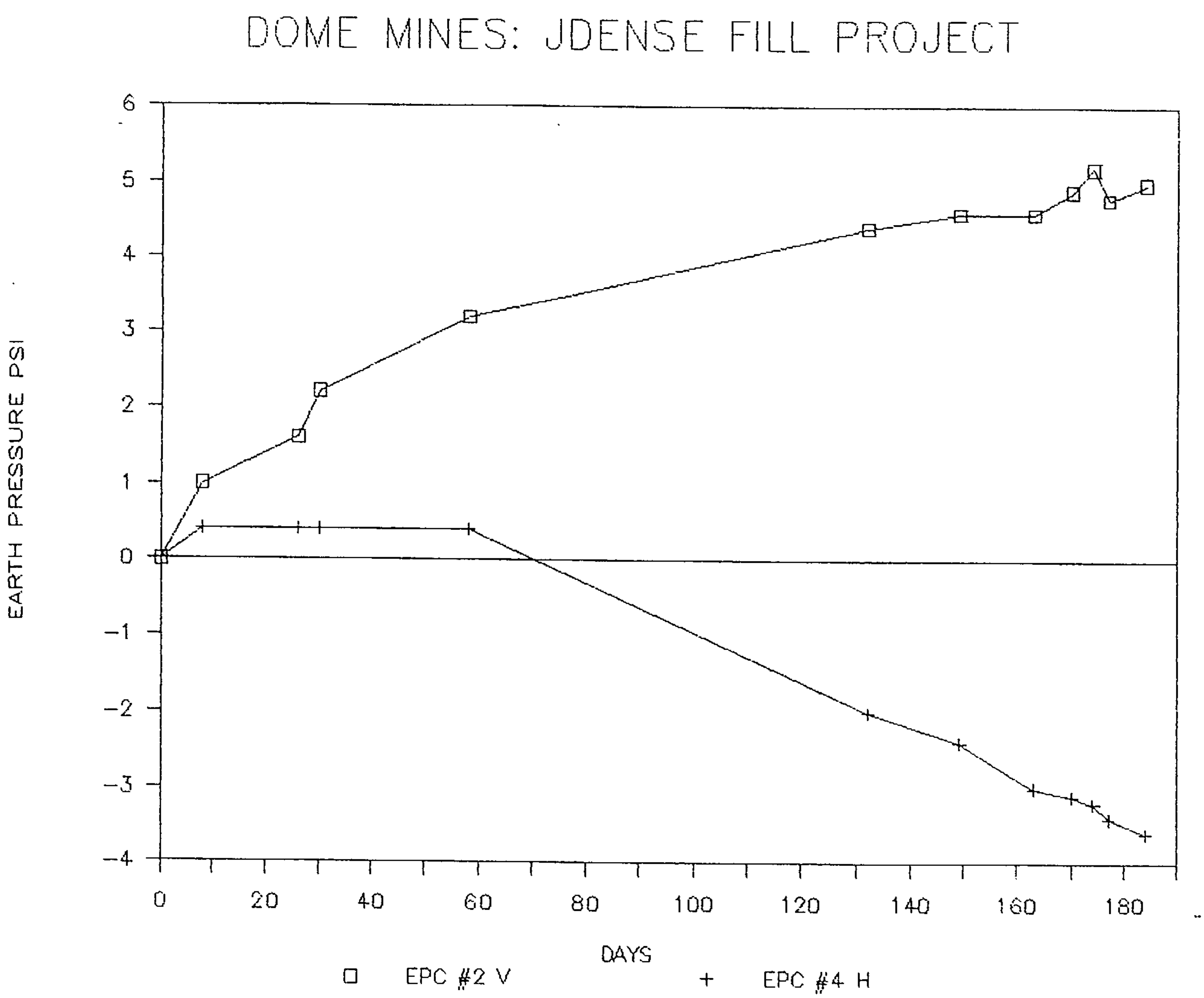


FIGURE 10

PASTE FILL STUDY
DOME MINES
JDENSE FILL PROJECT CHART

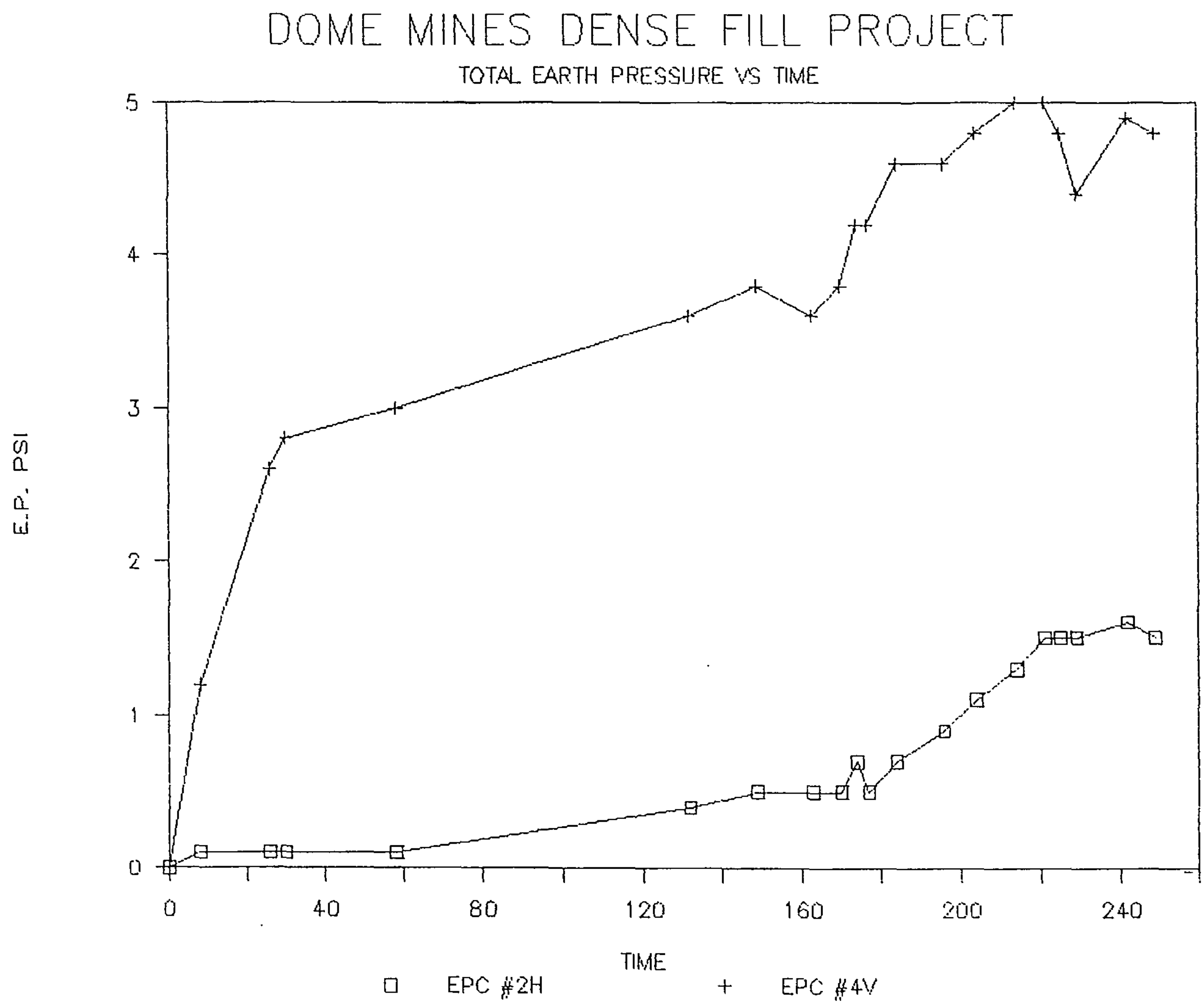


FIGURE II

PASTE FILL STUDY

DOME MINES

TOTAL EARTH PRESSURE
VS
TIME CHART

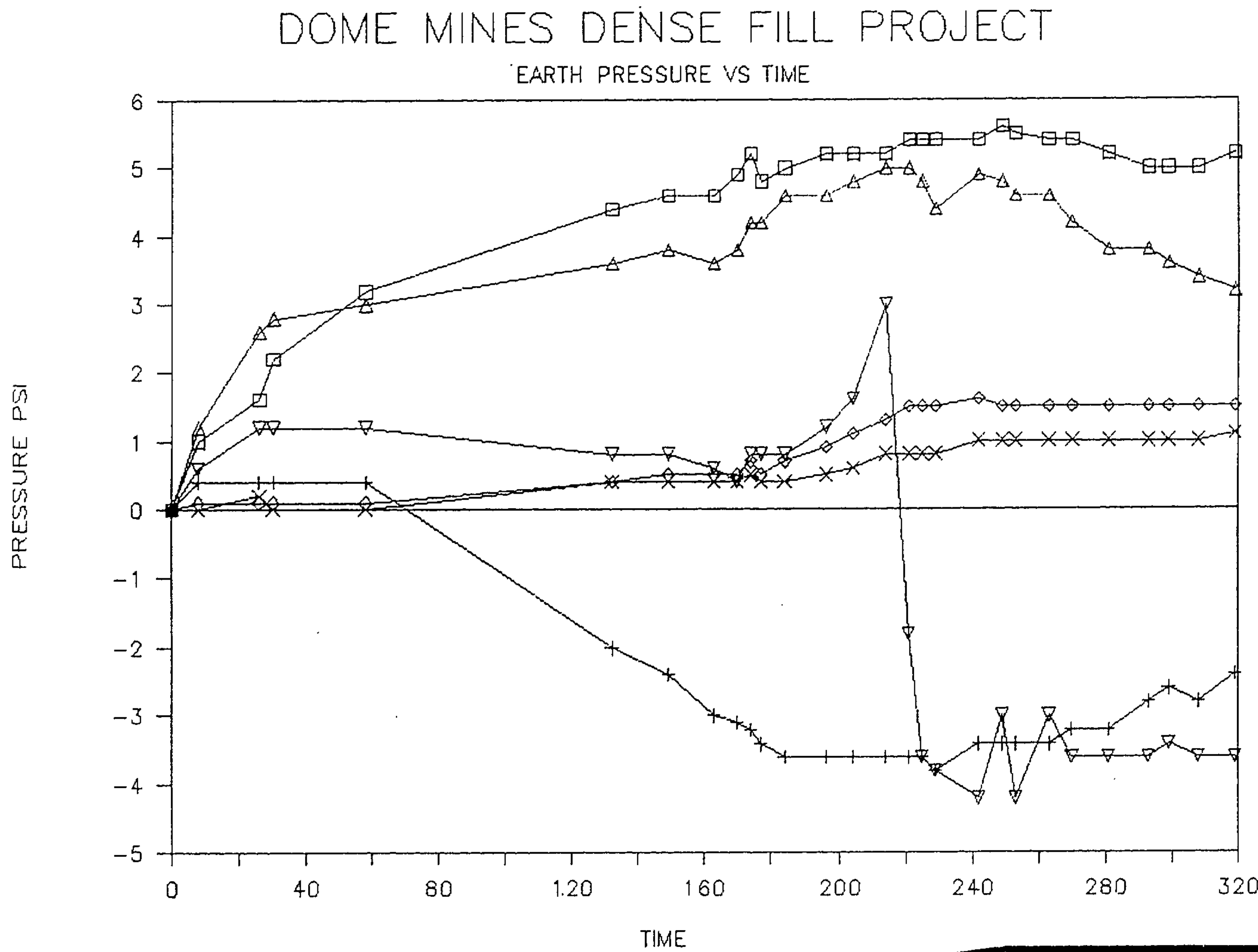


FIGURE 12

PASTE FILL STUDY
DOME MINES
EARTH PRESSURE VS TIME CHART

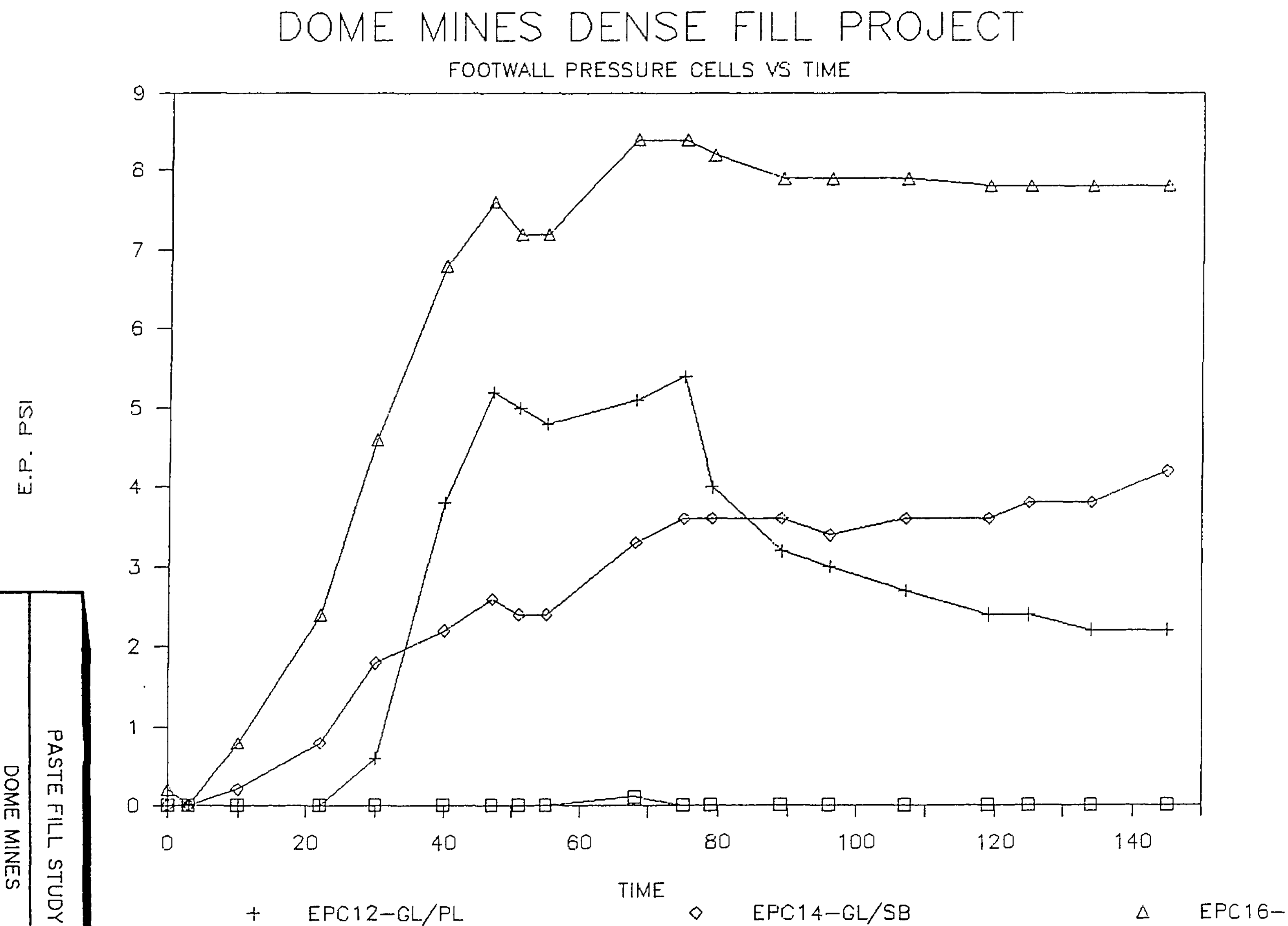


FIGURE 13

PASTE FILL STUDY

DOME MINES

FOOT PRESSURE CELLS VS TIME CHART

DOME MINES DENSE FILL PROJECT

TRIAXIAL ARRAY EPC /POSITIVE PIEZOMETER

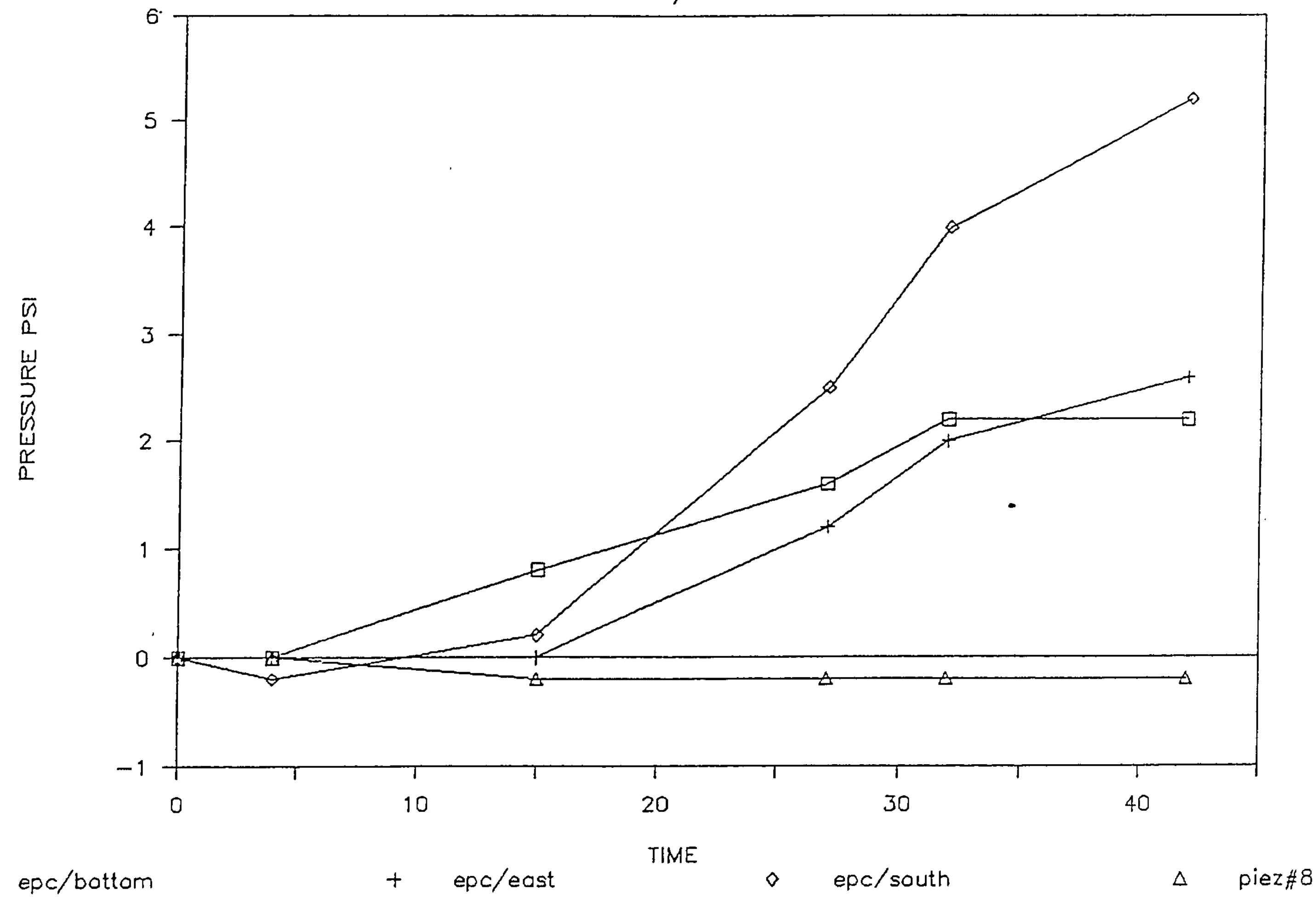
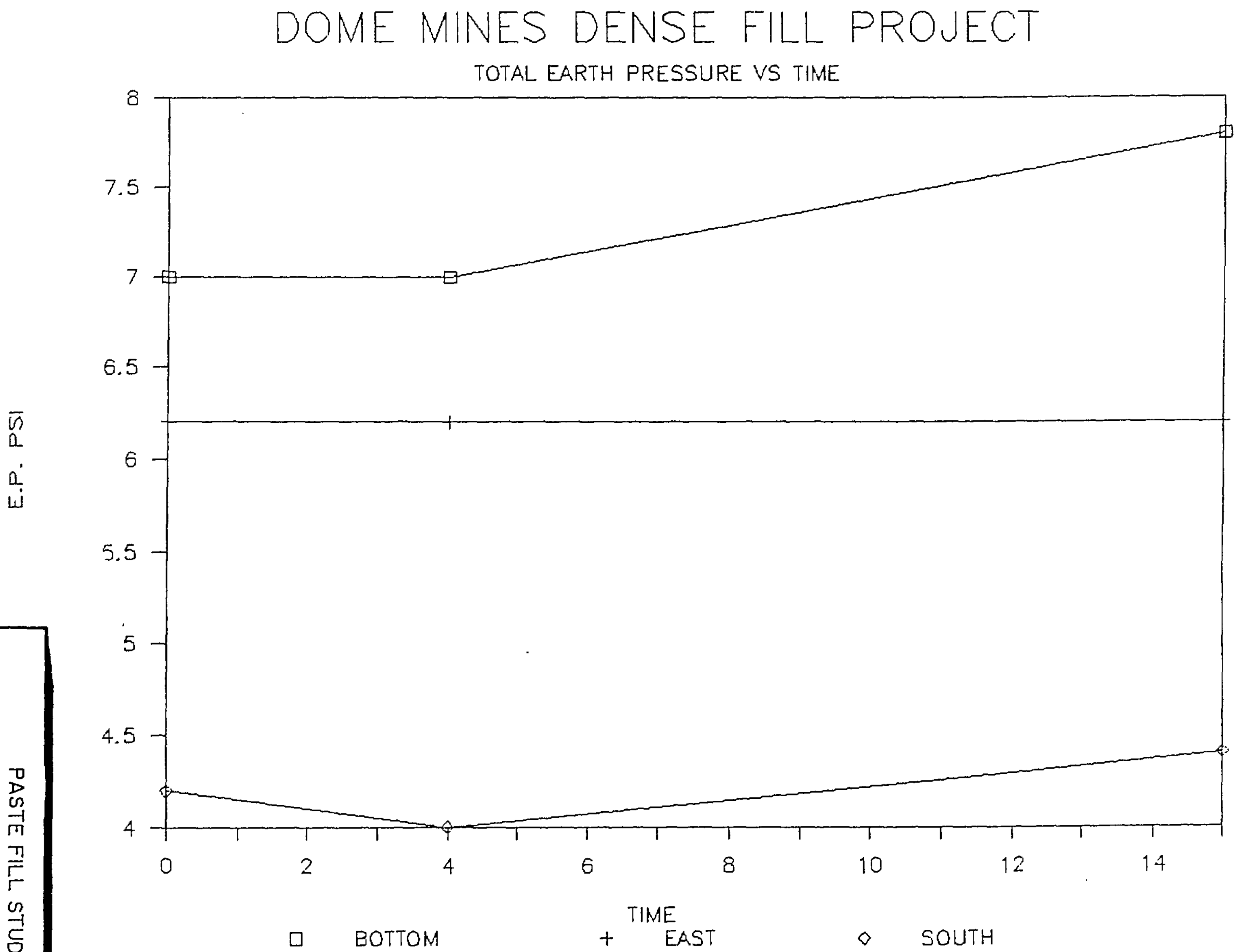


FIGURE 14

PASTE FILL STUDY

DOME MINES

TRIALIXIAL ARRAY EPC
VS
POSITIVE PIEZOMETER



PASTE FILL STUDY

DOME MINES

TOTAL EARTH PRESSURE VS TIME CHART

FIGURE 15

7 LEVEL

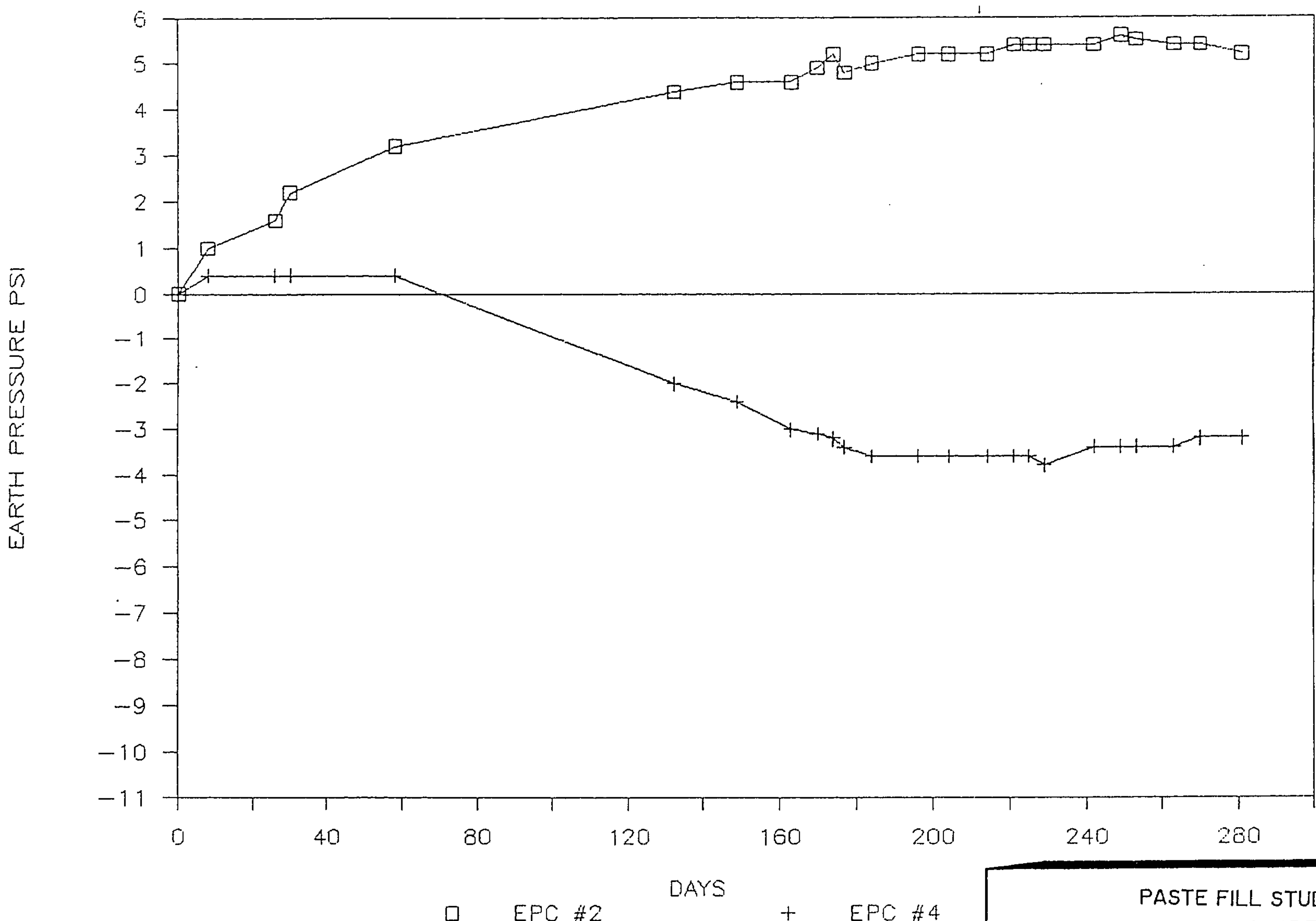


FIGURE 16

PASTE FILL STUDY
DOME MINES
7 LEVEL CHART

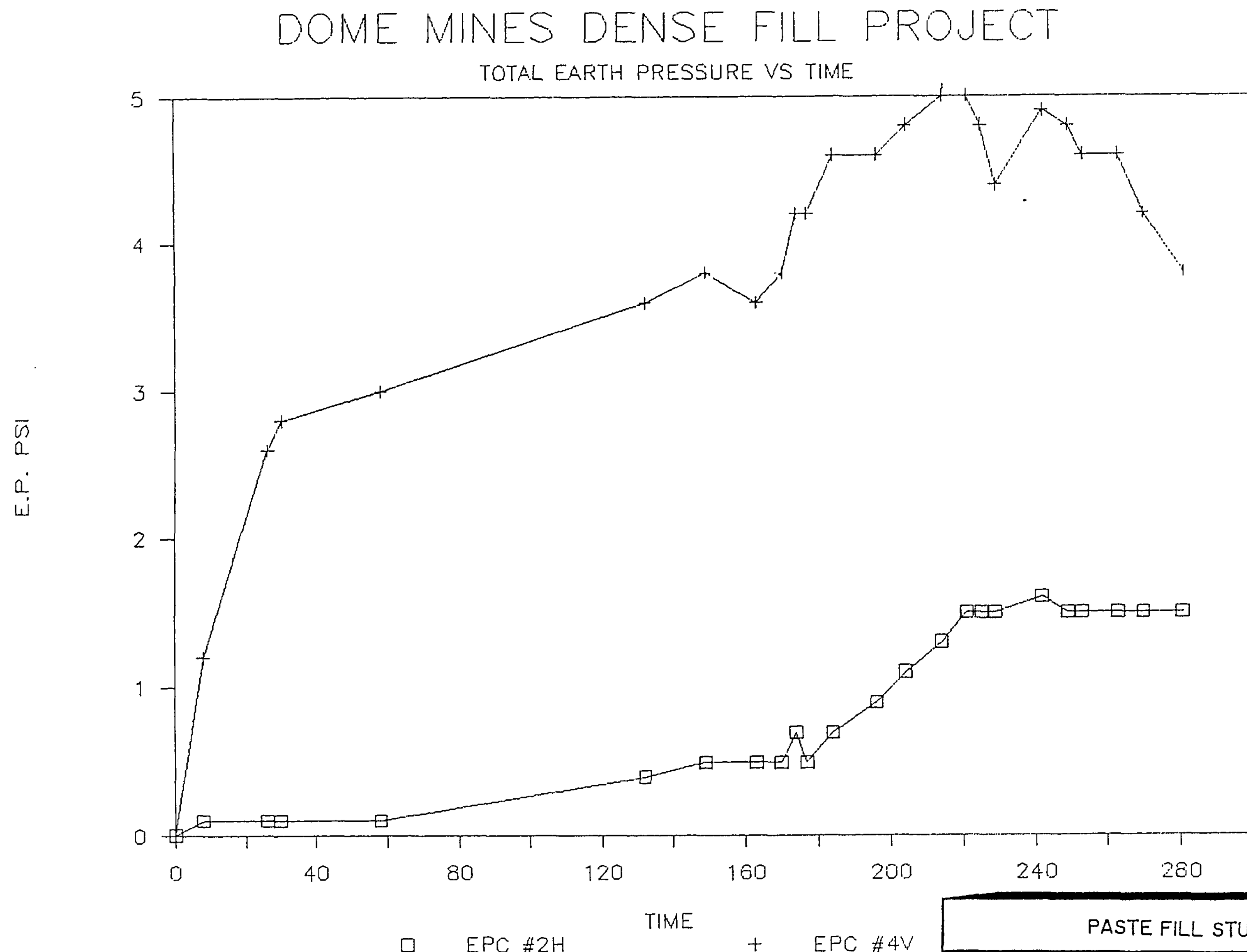


FIGURE 17

PASTE FILL STUDY

DOME MINES

TOTAL EARTH PRESSURE
VS
TIME CHART

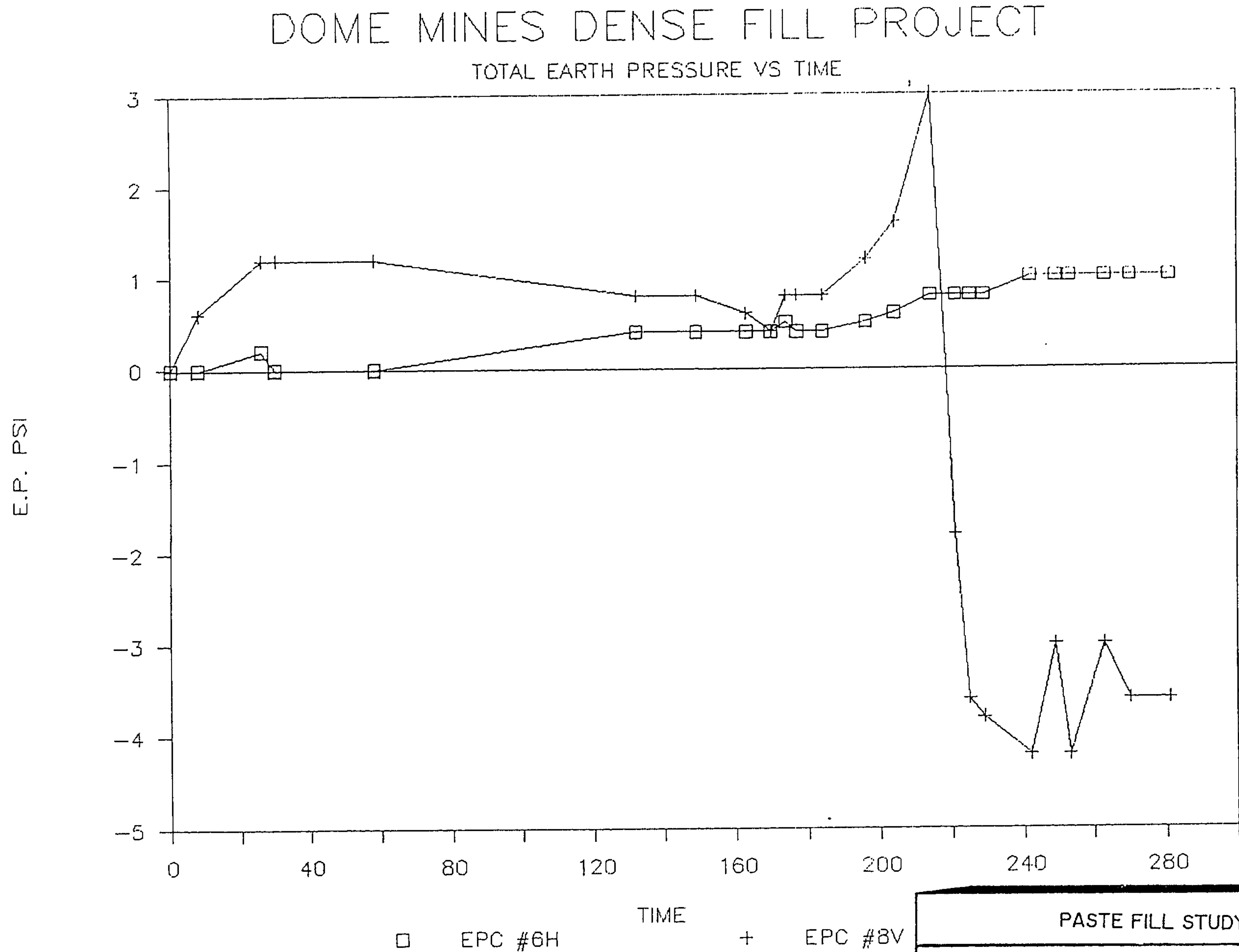
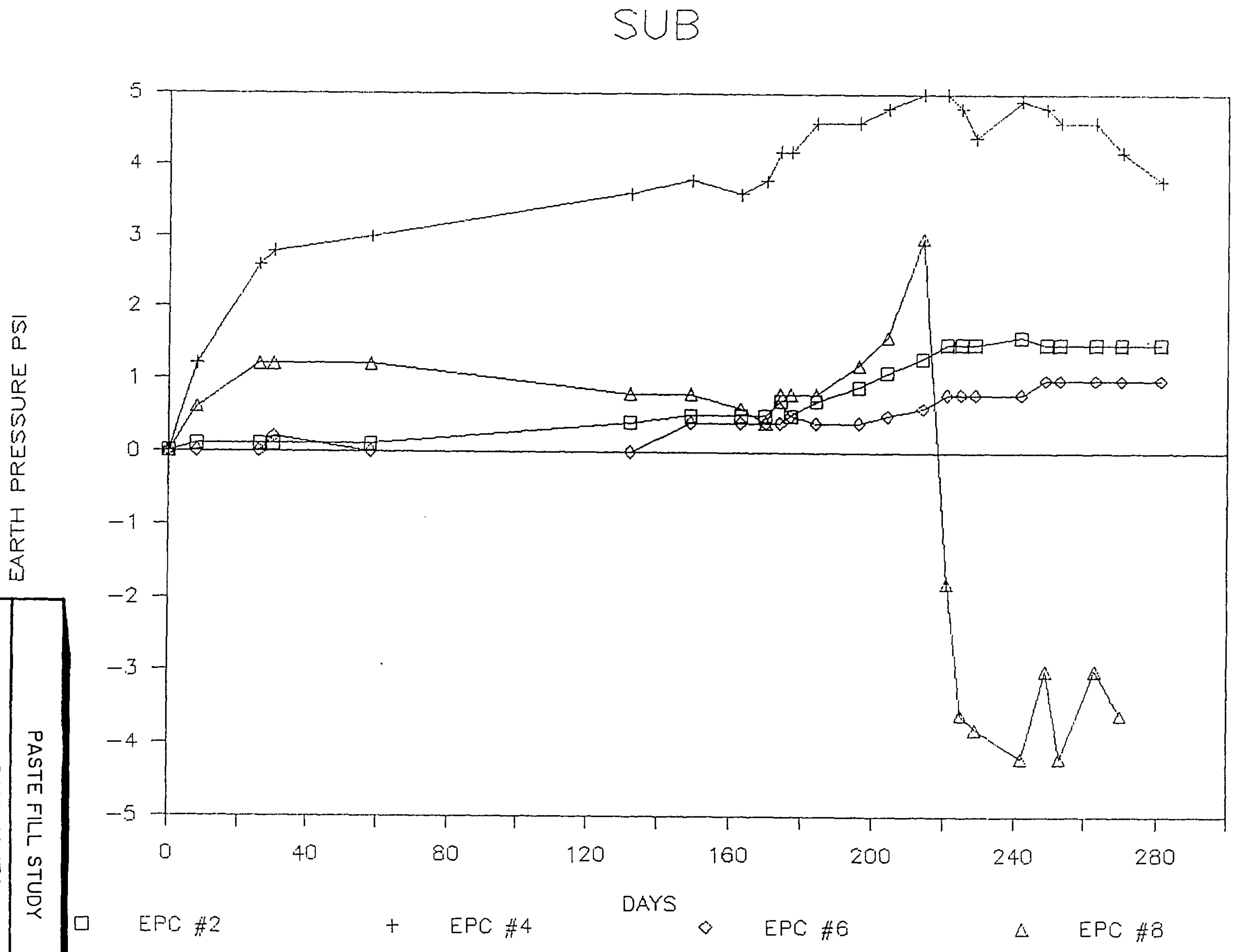


FIGURE 18

PASTE FILL STUDY

DOME MINES

TOTAL EARTH PRESSURE
VS
TIME CHART

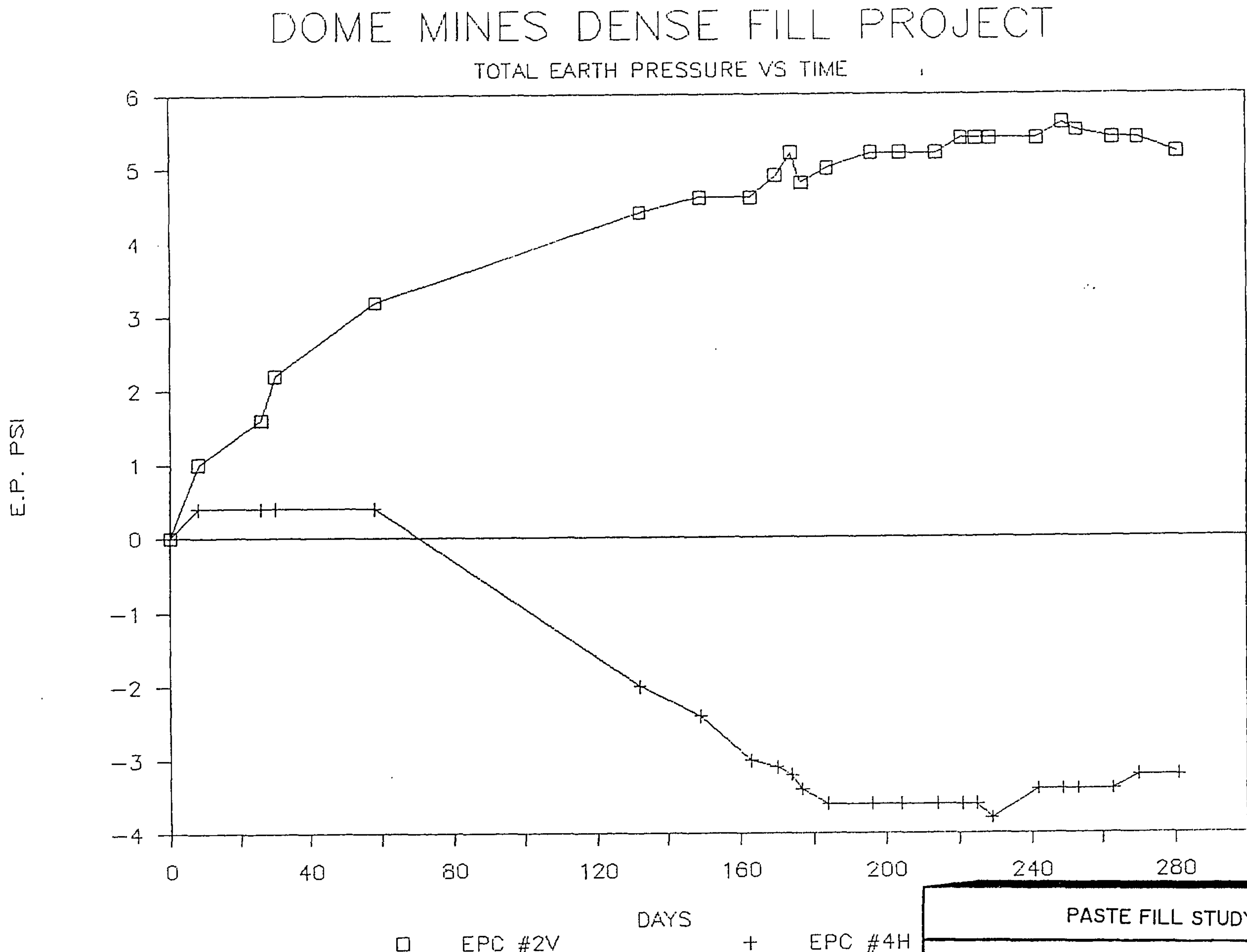


SUB CHART

DOME MINES

PASTE FILL STUDY

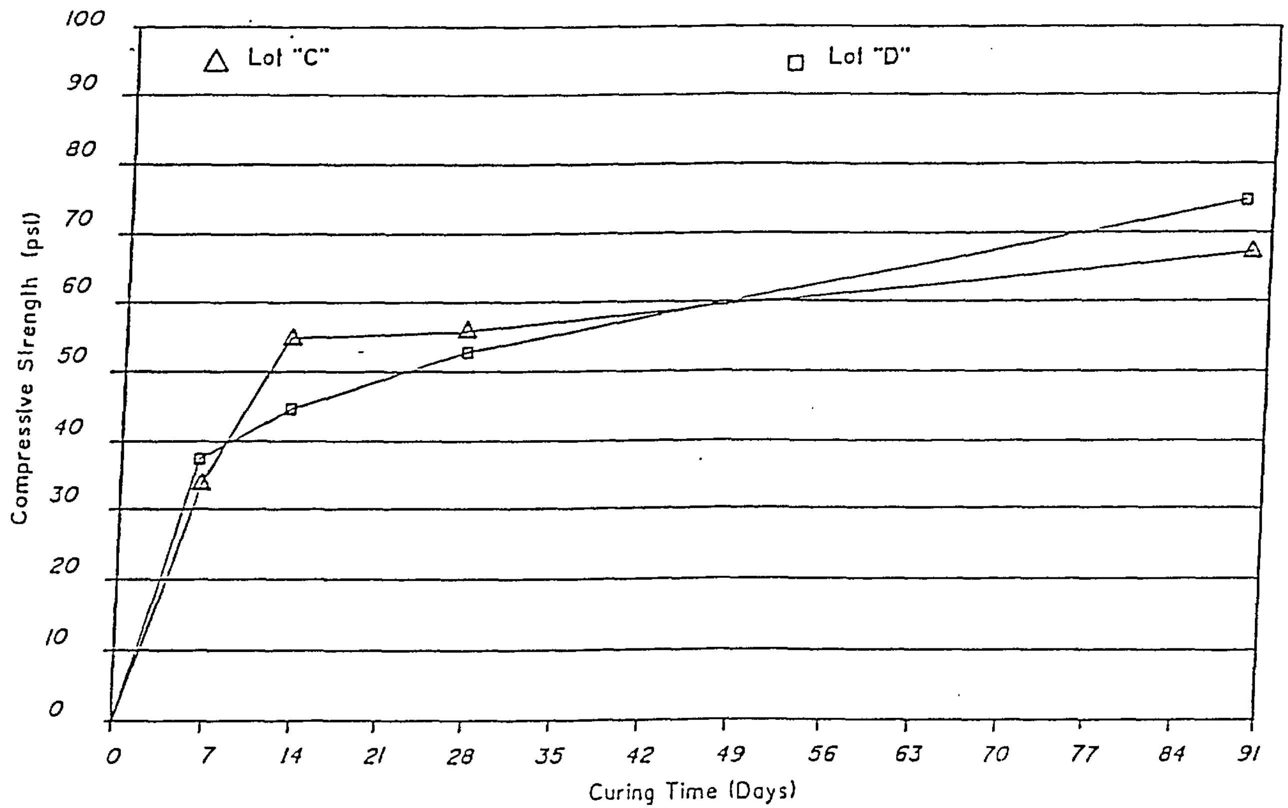
FIGURE 19



PASTE FILL STUDY
DOME MINES
TOTAL EARTH PRESSURE VS TIME CHART

FIGURE 20

DOME MINE : HIGH DENSITY BACKFILL
35:1 CAST ON SITE

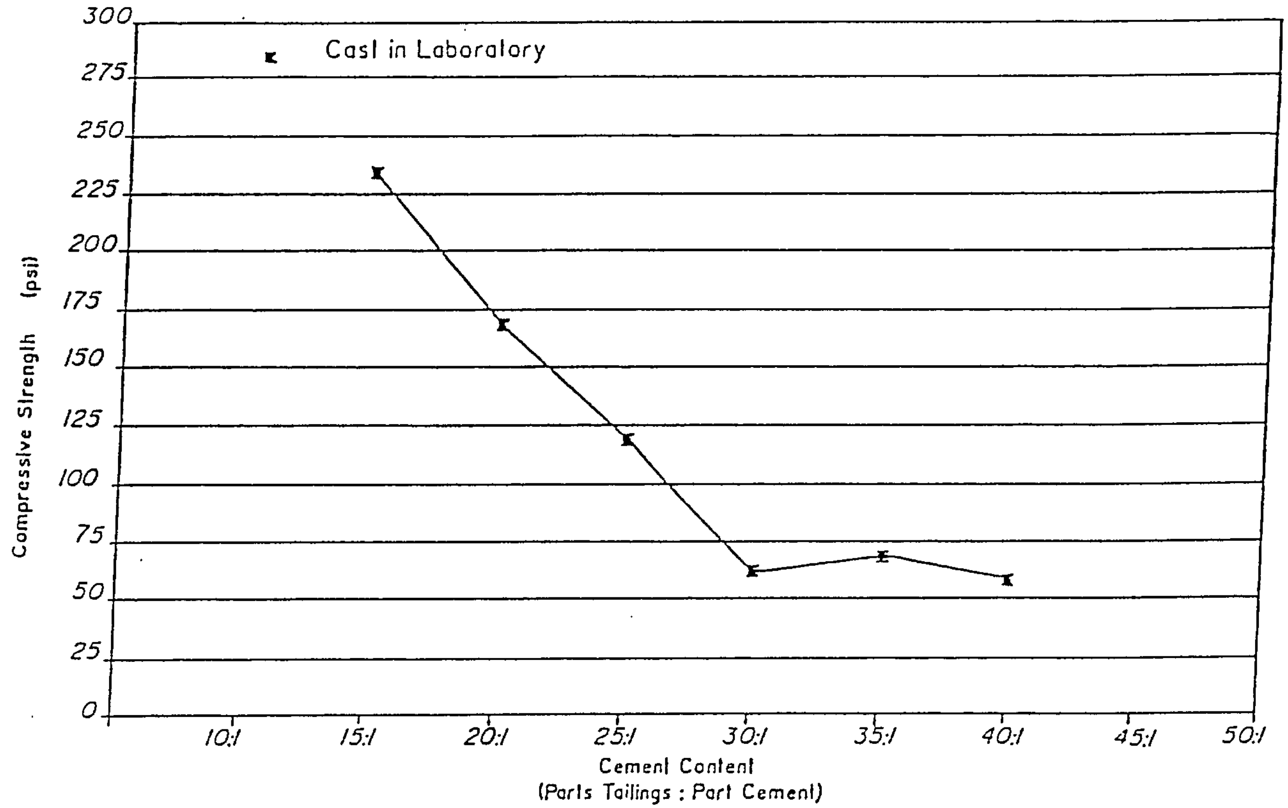


COMPRESSIVE STRENGTH
VS
CURING TIME

FIGURE 21

PASTE FILL STUDY
DOME MINES
COMPRESSIVE STRENGTH VS CURING TIME

DOME MINE : HIGH DENSITY BACKFILL
28 DAY STRENGTH



COMPRESSIVE STRENGTH
VS
TAILINGS CEMENT RATIO

FIGURE 22

PASTE FILL STUDY
DOME MINES
COMPRESSIVE STRENGTH VS TAILINGS CEMENT RATIO

DOME MINES LIMITED

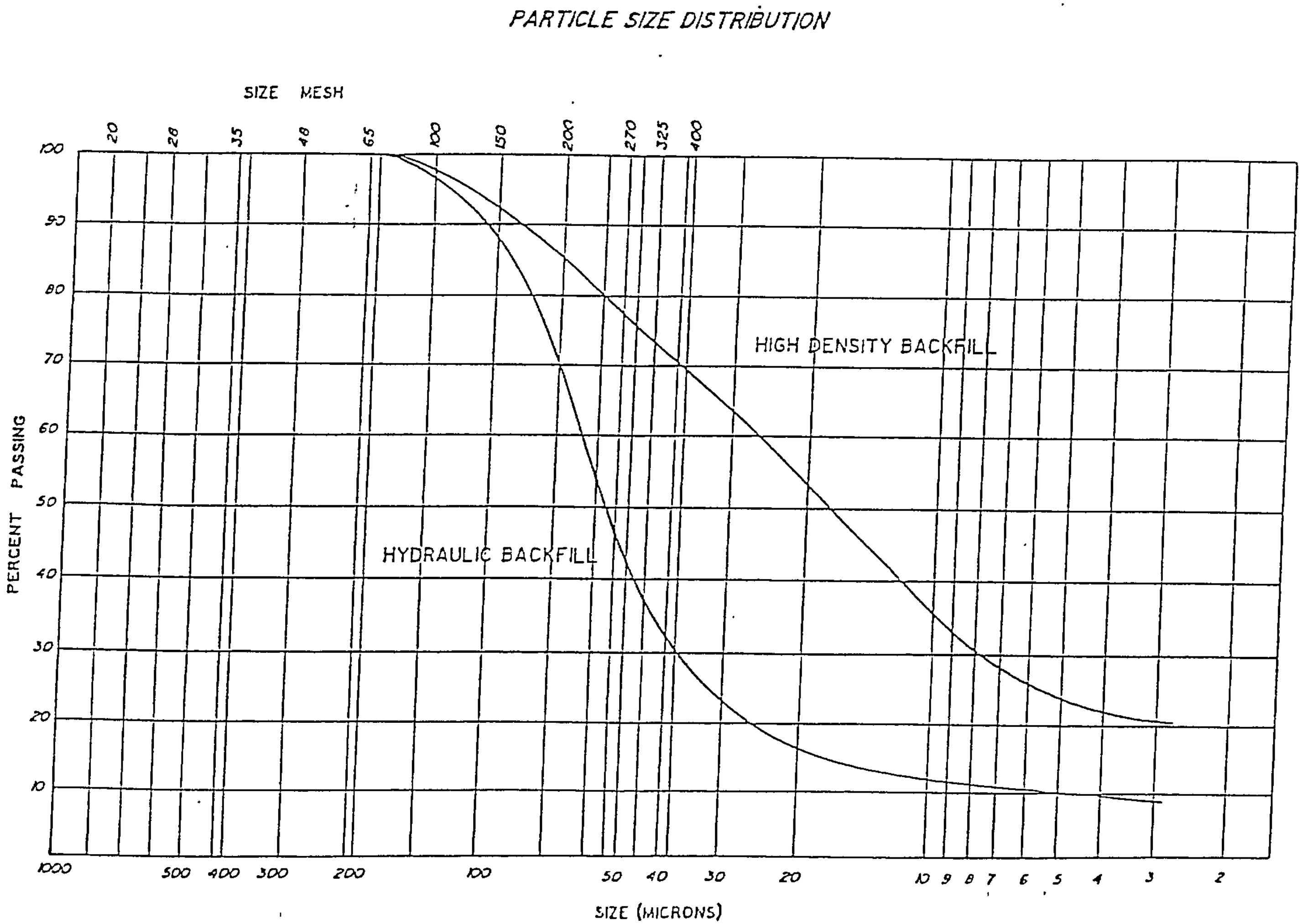


FIGURE 23

PASTE FILL STUDY

DOME MINES

PARTICLE SIZE DISTRUCTION

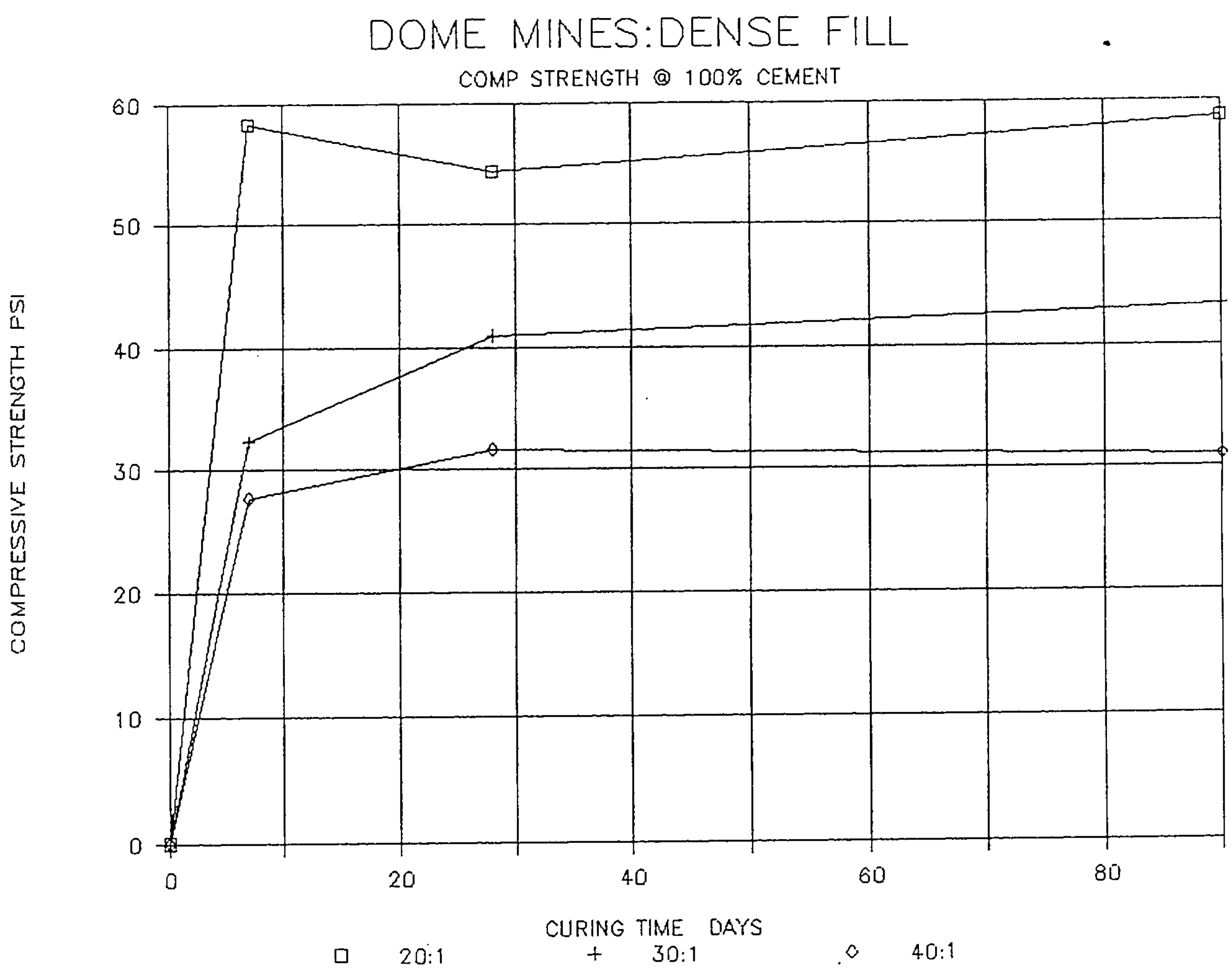
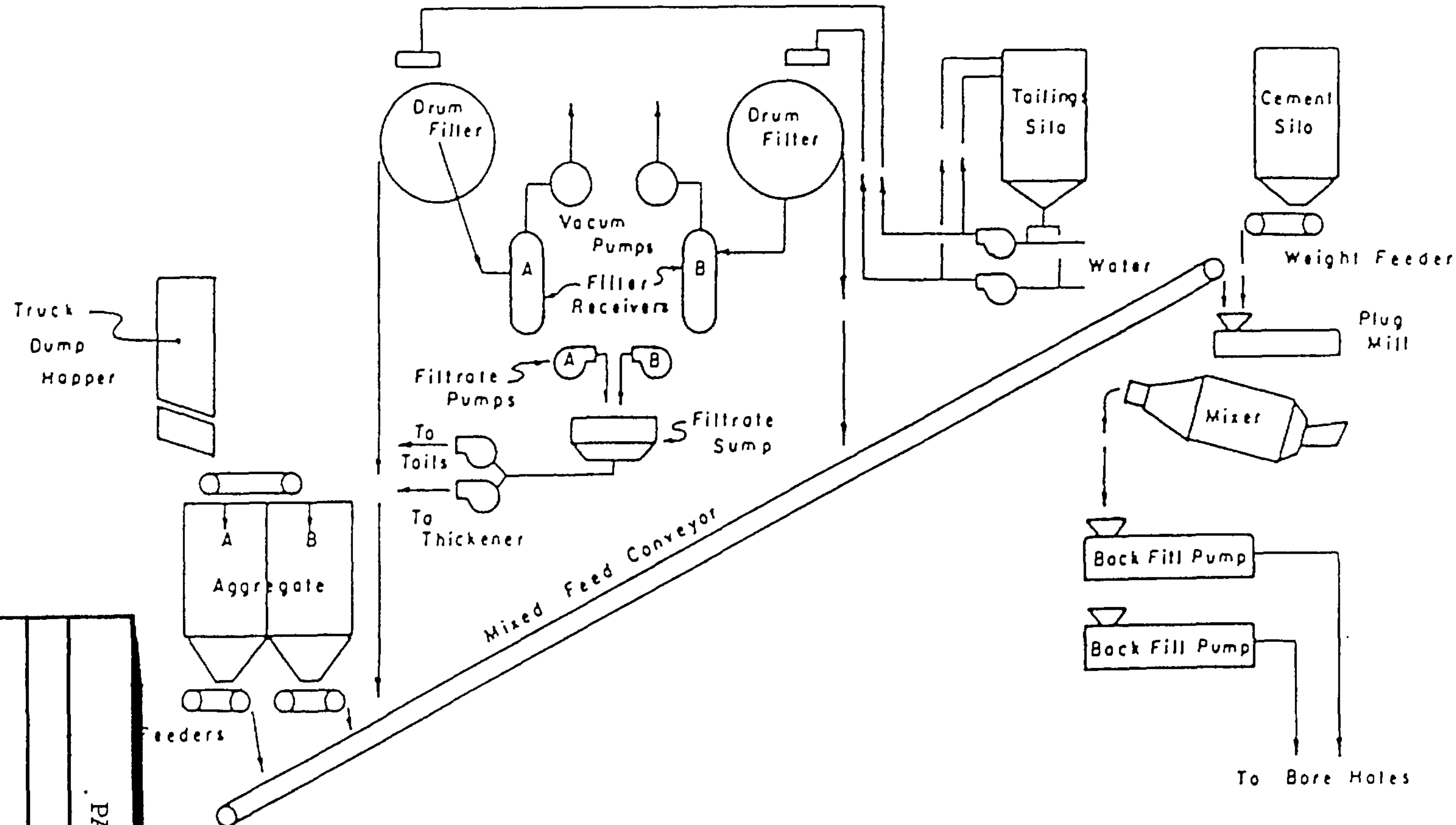


FIGURE 24

PASTE FILL STUDY

DOME MINES

COMPRESSIVE STRENGTH @ 100% CEMENT CHART



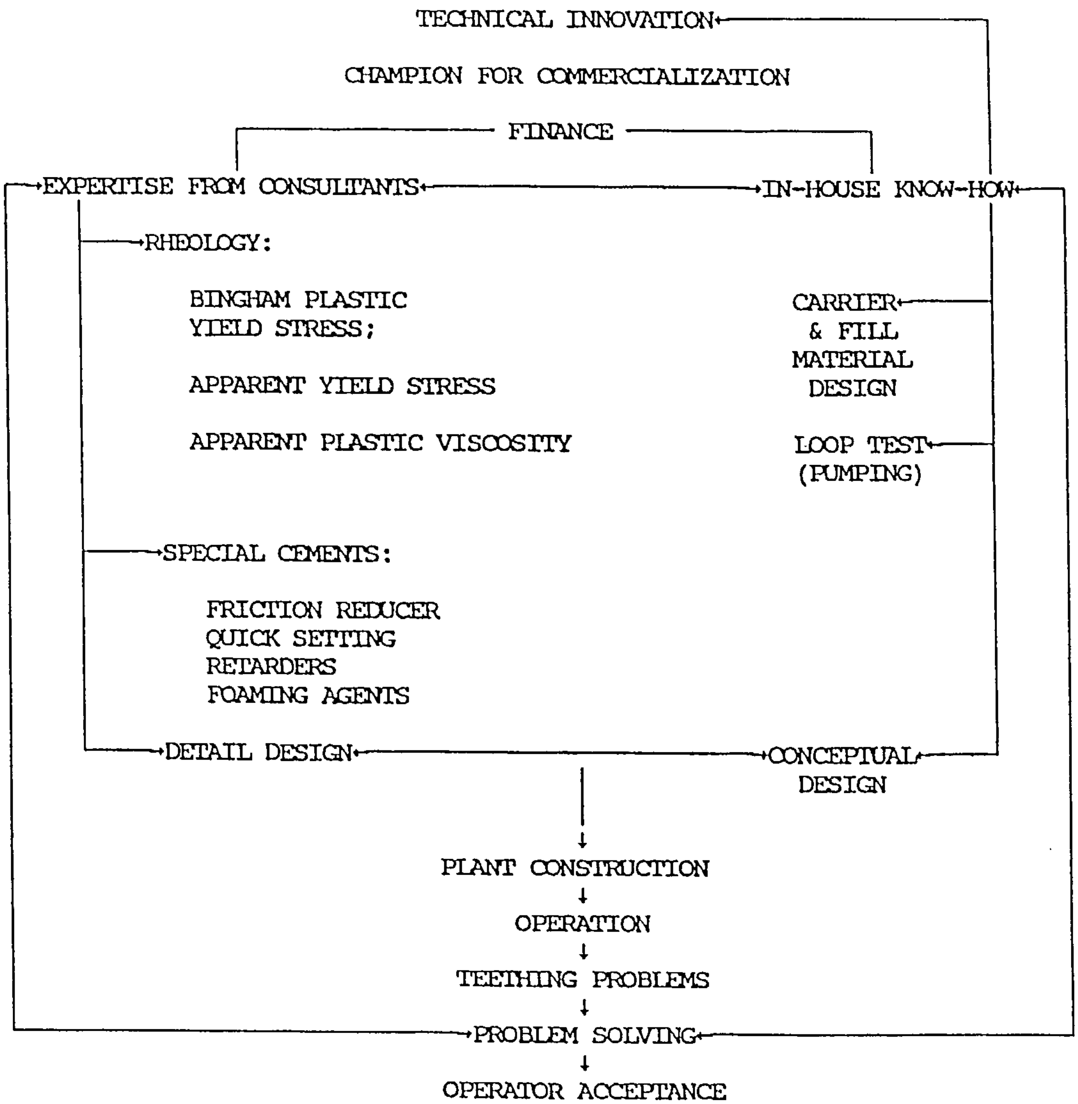
Elura Mine Backfill Plant – Flow Diagram

PASTE FILL STUDY

DOME MINES

ELURA MINE BACKFILL PLANT-FLOW DIAGRAM

FIGURE 25



-ELEMENTS FOR SUCCESSFUL INSTALLATION OF A SURFACE PASTE FILL PLANT

FIGURE 26

PASTE FILL STUDY
DOME MINES

APPENDIX I

RESEARCH DRILLING PROGRAM BY TROW LIMITED

Trow

RESEARCH DRILLING PROGRAM
HIGH DENSITY BACKFILL
DOME MINES FACILITIES
SOUTH PORCUPINE, ONTARIO

PREPARED FOR:

DOME MINES LIMITED

TROW ONTARIO LTD.
Toronto, Hamilton, London,
Sudbury, North Bay, Ottawa

Project: S871465R
September 11, 1987

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(705) 674-9681

RECEIVED SEP 2 2 1987

Trow

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DRAWINGS

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HIGH DENSITY BACKFILL
DOME MINES FACILITIES
SOUTH PORCUPINE, ONTARIO

1.0 INTRODUCTION AND TERMS OF REFERENCE

It is understood that Dome Mines Limited, South Porcupine operation, has undertaken a CANMET research contract related to full scope in-situ testing and instrumentation of its high density backfill.

Subsequently, Dome Mines Limited retained the services of Trow Ontario Ltd. to undertake part of their contract with an investigative drilling program to encompass the following general terms of reference:

1. Investigate drilling techniques and methods for drilling of mine fill for the purpose of sample recovery and instrumentation.

2. Secure relatively undisturbed samples of mine fill where possible.

3. Attempt to provide suitable test holes for instrumentation and assist in installations

4. Record results of drilling operations, detail any special equipment or modifications used, and submit a written report, with photographs, detailing the field work and drilling recommendations that result from this program.

The written proposal by Trow for the above work was submitted on November 22, 1985; however, the field work did not commence until May 11, 1987, A second, short, "follow-up", field testing phase was initiated on August 17, 1987.

An initial meeting was held at Dome Mines on March 24, 1987, at which time it was agreed to commence the field work in early May. Furthermore, it was agreed that Trow would keep to the original proposal as much as possible with regard to the above terms of reference and the original costs outlined in the 1985 proposal.

It was also agreed that Trow would make available, if necessary, their Texam Pressuremeter for limited testing should any problems arise with the large Probex model to be used by CANMET.

2.0 DRILLING UNITS

For the purpose of this investigation, a JKS Boyles portable diamond drill, supplied by DBM Technical Drilling, was utilized for the shallow test holes accessed directly onto the mine fill face. The drill was adapted for air power and provided with a gear reduction unit for rpm control. A typical drill set-up is illustrated on the enclosed photographs, Nos. 1 and 2, in Appendix 3.

For the deeper mine fill test holes accessed through rock, a BBU-2 air powered unit, supplied by N. Morissette Canada Inc., was used. This unit was adapted with wire line capabilities and hydraulic head. A typical drill set up is illustrated on the enclosed photograph No. 3 in Appendix 3.

3.0 DRILL EQUIPMENT (IN-HOLE)

A variety of rotary in-hole equipment was experimented with for the purpose of sample retrieval and instrumentation. Typically, the following variety of devices was used:

NW core barrel with various adapted casing sizes

BW core barrel with various thin-wall core bits

continuous flight augers with a modified split barrel sampler

4.0 BOREHOLE LOCATIONS AND DETAILS

All drilling was performed at the 750 foot level of the Dome Mines facilities, South Porcupine, Ontario, and general borehole locations are shown on the enclosed Drawing 1.

Details of the boreholes are shown on the enclosed borehole logs in Appendix 1. The three boreholes undertaken with the BBU-2 are designated boreholes A, B and C. The boreholes undertaken with the portable JKS drill are designated boreholes 1 to 7, inclusive.

5.0 PRESSUREMETER TEST RESULTS

Pressuremeter tests undertaken by CANMET are to be reported separately by others and as such, details are not included.

Although pressuremeter tests were to be performed by others, it was agreed that additional tests using Trow's Texam pressuremeter would be useful, particularly since we had undertaken similar tests recently on another mine backfill drilling project. A limited amount of data was obtained by our field personnel yielding preliminary geotechnical parameters on the backfill. These results are included in the attached Appendix 2.

The results have been calculated with the use of our current computer data reduction program for Texam pressuremeter data. It is our opinion that the ranges of Young's Modulus (Eo) are reasonable; however, problems with borehole diameter, together with some limitations of the testing equipment, lead to inconsistencies with other parameters.

6.0 DISCUSSIONS

6.1 Mine Fill Reaction to Drilling:

On this project, mine services, set-up locations, procedures and general instructions were supplied by Dome Mines Ltd. Dome also supplied general information regarding the high density fill. This information, together with preliminary drilling results, indicated that the mine fill material at the test locations was fine grained, very moist to wet, and sensitive to disturbance. Typical moisture content determinations as performed on samples secured from test hole #1 are summarized in the following Table 1.

TABLE 1

MOISTURE CONTENTS

Sample No.	Depth (ft.)	Moisture Content (% dry weight)
1	0 - 1.5	22.0%
2	1.5 - 3.0	23.1%
3	3.0 - 4.5	19.6%
4	4.5 - 6.0	22.1%
5	6.0 - 7.5	20.8%
6	7.5 - 9.0	22.7%
7	9.0 - 10.5	21.7%
8	10.5 - 12.0	21.0%
9	12.0 - 13.5	19.2%
10	13.5 - 15.0	16.8%

The relatively high degree of water content, together with the fine grained mine fill, resulted in localized disturbance and dilatancy during drilling. Typically, with even light to moderate drill force and rotation, the mine fill has a tendency for "sloughing" in the immediate area of the drill hole. An example of this reaction is shown in Appendix 3, photograph No. 4.

6.2 Use of Water/Air:

The use of water and air for removal of mine fill cuttings during drilling operations was, for the most part, unsuccessful. Even under controlled volume and pressure conditions, excess material disturbance occurred. Air in particular was found to migrate into the adjacent mine fill and was observed affecting the mine fill up to distances of 3 feet laterally from the drill hole. The use of water compounded the problem of the already relatively high in-situ moistures, resulting in an increased tendency for "sloughing", loss of material, general disturbance and saturation of samples.

6.3 Use of Core Barrels, Casings & Thin Wall Bits:

The design of the various sample barrels, casings and thin wall industrial equipment is based on the efficiency and use of air or water to provide clearance and removal of material cuttings during drilling. As previously noted, the use of either air or water induces adverse conditions during drilling operations. At best, it is possible to reduce the use of air and water to a minimum and to increase bit pressures and feeds to effectively "jam" samples into the sampler. As a consequence, a disturbed drill hole is produced. In addition, it was very difficult to extract the sample from a solid wall sampling device, since the sample had to be "hammered out" or forced out by mechanical or hydraulic jacking methods.

6.4 Use of Modified (Serrated) Casing:

Based on the lack of success using water and air as a "flushing" process, it was decided to attempt a "dry" technique utilizing a serrated NQ drill rod. For this purpose, a length of NQ rod was cut at one end and sections of the metal "twisted" to provide a cutting head as shown on the enclosed photograph No. 5 in Appendix 3

The use of the serrated casing did in fact provide increased sample recovery, with substantially less hole disturbance than the use of air and water. Problems encountered, however, included the use of increased drill pressure, lack of any effective cutting removal, build up of heat (casing became very hot), and the difficulty of sample extraction from the casing.

6.5 Use of Continuous Flight Augers:

For maintaining optimum drill hole tolerances, and for providing access for sampling, the continuous flight augers were found to be effective for this project.

Under controlled feed and rotation conditions, the flight augers were found to provide the least amount of material disturbance, while providing a suitable borehole tolerance for instrumentation purposes.

Several problems were experienced, however, which resulted mainly from the auger sections being connected loosely by auger pin inserts causing deflection of the augers and subsequent drill hole alignment variations.

Additionally, standard auger bits are normally slightly oversize in relation to the diameter of the flight auger sections. This results in inefficiency in removing cuttings; consequently, drill holes, in some cases, had to be re-augered several times to ensure a smooth drill wall.

6.6 Fabrication & Use of Modified Split Barrel Sampler:

Based on the drilling and test data obtained to this point, the critical question of effective sample retrieval was of major concern. Subsequently, it was determined that any effective sampler for this project must meet the following criteria.

- Sampler must be able to penetrate the mine fill with a minimum amount of disturbance and without the use of air or water.

- Sampler must be able to effectively remove excess mine fill cuttings during sampling operations.

- Extraction of mine fill from sampling device must minimize disturbance of sample.

These sampling requirements were reviewed and a basic sampler, incorporating the use of continuous flight augers with split barrel capabilities, was designed and fabricated. Essentially, the basic concept was to use a normal split barrel sampler, incorporating continuous flights around the sampler periphery. The flights would be aligned to provide spherical continuity, but allow easy dismantling of the sampler for sample recovery.

A prototype was fabricated and is shown on photograph Nos. 6, 7 and 8 in Appendix 3. One important feature of this sampler is the machine cut of the flights to allow for the disassembly of the sampler.

The sampler was tested on the Dome Mines Limited project and sample recovery was in the range of 80% to 100% of relatively undisturbed mine fill (based on a single shallow test hole - see borehole log 7). Typical sample recovery utilizing this sampler is shown on photograph No. 9 in Appendix 3.

One of the problems in the design of the sampler is related to penetration of dense mine fill. Although the sampler can effectively penetrate relatively "loose" mine fill, it has not been provided with an adequate cutting head to penetrate the "denser" mine fill material. Additionally, the flights require modification with regard to length, thickness, pitch and frequency. The concept, however, appears to have the potential for positive retrieval of undisturbed mine fill samples, particularly for the fine grained type of material being used at Dome Mines.

The performance of the augers and sampler is a function of the type and power of the drill unit. For example, small drill units would restrict sampling and augering to relatively shallow depths only.

6.7 Pressuremeter Instrumentation:

As part of this investigative program, we were requested to assist in the installation of various CANMET pressuremeter apparatus. This work is expected to be reported separately by CANMET.

Trow Ontario Ltd. attempted to undertake portions of the pressuremeter testing with a Texam pressuremeter after difficulties were experienced in the early phase (boreholes A, B and C) related to the installation of the Probex pressuremeter in the BBU-2 boreholes. Consequently, we advanced a series of auger holes to incorporate the use of Trow's Texam pressuremeter. In addition, we assisted in the installation of a pressure probe (Geocell) supplied by Dome Mines Ltd.

Some problems were encountered installing and using the pressuremeter equipment in the boreholes. In the case of the CANMET apparatus, a combination soil/rock pressuremeter was used, which ultimately proved too heavy and bulky for installation by hand on the inclined holes drilled by N. Morissette Canada Inc.

Additionally, all three probe types, although provided with conical tips, tended to "settle" into the mine fill during installation forcing material ahead of the probe and causing disturbance and hole blockage. This problem is complicated by the deflection of the boreholes as a result of drilling.

6.8 Drill Unit Performance:

As previously discussed, a portable, air powered, JKS Boyle diamond drill was used for drilling trials at the mine fill face, whereas a BBU-2 unit with hydraulic capabilities was used for the deeper test holes accessed through the pillar wall.

In both cases, these drill units were found to be unsuitable in general for overall mine fill testing.

The portable unit was found to be useful to depths of up to 30 feet on inclined holes, but did not have sufficient torque for all phases of the testing trials. Additionally, its manual chain-feed restricted efficient, controlled feed rates. The BBU-2, on the other hand, had more than sufficient torque but could not accurately control low rpm and penetration parameters for the restricted testing required. Furthermore, the weight and size of the BBU-2 power unit, hydraulic head, pumps and ancillary equipment makes this unit cumbersome and requires substantial set-up time.

7.0 RECOMMENDATIONS

7.1 Continuous Flight Auger Concept:

It is our opinion that fine grained mine fill, typical of the Dome Mines fill, can be drilled to enable instrumentation and retrieval of undisturbed samples utilizing a suitably designed continuous flight auger concept.

It has been shown that the proper use of continuous flights can produce the following:

1. A suitably toleranced borehole for instrumentation purposes without introducing the unknown effects of pressurized water and air.

2. Retrieve samples of mine fill for general grain size analyses, moisture content determinations, etc.

3. A modified continuous flight split barrel sampler, suitably designed, can secure reasonably undisturbed samples which, for the most part, are adequate for triaxial and uniaxial testing, etc.

4. Ultimately, (and given sufficient basic data on physical mine fill properties), a properly designed sampler and/or mine auger unit could be used for simple and quick confirmation of physical properties on exposed mine fill faces.

Based on the foregoing, it is our recommendation that the use of a properly designed, continuous flight concept, in combination with normal underground diamond drilling operations, should be fully researched.

Suggestions for research parameters and areas of investigation are detailed in the following paragraphs.

7.2 Drill Equipment:

A list of available underground drills and power units should be compiled from various manufacturing and marketing sources, together with technical data related to drilling capacities, torque and rpm data, power source requirements and adaptability to modification for continuous flight applications.

This portion of the listing should include data from the mining industry regarding in-house equipment and power sources which are in predominant use within the industry.

Subsequently, the data should be correlated and evaluated for recommendations towards: (1), an all purpose drill unit adapatable for full-scale mine fill testing, including rock access drilling: (2), adaptability of current, light weight, underground drill units to continuous flight systems for quick penetration of open mine fill faces.

For an all purpose drill, it is expected that the emphasis should be on the economical modification of existing available equipment which is light weight, easily assembled, compact and capable of drilling approximately 200 feet with 3.0 inch to 3.5 inch diameter.

7.3 Continuous Flight Auger Systems:

Available continuous flight auger systems should be evaluated with regard to types of flight augers, auger diameters related to instrumentation requirements, auger to auger bit size ratios and types of auger bits, etc. Additionally, the use of light weight alloy augers should be considered as part of the overall evaluation.

The intent of this evaluation would be to determine the most suitable unit which could be readily adapted in an underground environment.

7.4 Continuous Flight Split Barrel Sampler:

The concept of a split barrel sampler adapted for use with continuous flights should be pursued.

As shown on this project, the concept was generally successful, but requires refinement with regard to design of the flights, as well as a suitably designed cutting head.

Ultimately, this type of sampler could provide a quick and relatively easy means of securing undisturbed samples for quality control testing of mine fill.

Field trials should be undertaken to further refine and evaluate the overall effectiveness of this system.

7.5 Instrumentation:

While the evaluation of instrumentation was not part of Trow Ontario Ltd.'s overall terms of reference, a review of the various types, sizes and operations of instrumentation should become an integral part of backfill testing. It would be ideal to incorporate a system which could utilize a single test hole for both sampling and instrumentation. Additionally, any instrumentation used (i.e., such as the pressuremeter) should be modified to ensure that similar problems experienced on this project are avoided. For example, the probe should be as short and as light weight as possible, with a tapered, conical head to minimize disturbance of the borehole side walls. The probe diameter should match the auger head size less 0.1 mm for tolerances. Couplers on the installing rods, which would be typically much smaller than the borehole, should be of the same diameter of the probe to act as stabilizers.

8.0 CONCLUSIONS

Based on this test drilling program, it appears that traditional diamond drilling methods, utilizing air and water flushing methods, will not provide an effective and economical means for mine fill sampling and instrumentation. The use of pressurized air or water cannot be sufficiently controlled to avoid both saturation of the retrieved samples and/or disturbance of the side walls of boreholes in mine fill. Difficulties in retrieving undisturbed samples is also a problem.

Accordingly, our recommendation to use the continuous flight concept is believed to be the most positive means of minimizing the variables inherent in mine fill drilling. A key issue includes the development of the continuous flight split barrel sampler. If the sampler design is optimized, the probability of retrieving undisturbed samples would, in our opinion, be increased.

Further research requires the collection of available data and modifying drilling equipment and drilling techniques.

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Trow

APPENDIX 1

SUMMARY OF BOREHOLE LOGS

BOREHOLE LOG
HIGH DENSITY FILL
DOME MINE FACILITY

BOREHOLE NO: A

STOPE: 552

DRILL: BBU-2

DIP: +30°

DEPTH: 0 - 53.0 ft.

LOCATION: Dome 750' Level

DEPTH (ft.)	HOLE DIAMETER (inches)	CORE RECOVERY	DRILLING METHOD	PRESSURE METER TESTS	COMMENTS
0 - 43.9	3.0	100%	NQ core barrel	None	Full water return
43.9 - 46.9	3.0	50%	NQ core barrel	None	No water return
46.9 - 53.0	3.0	50%	NQ core barrel	None	No water return
53.0	End of Borehole (Hole abandoned because of excess drill rod deflection.)				

Remarks:

-Encountered loose fractured rock and total water loss at 43.9 feet depth.
-Drill casing deflecting between 43.9 feet and 53.0 feet. Borehole
-terminated due to excess deflection restricting access to stope fill.
-Probex pressuremeter tests not performed.

BOREHOLE LOG
HIGH DENSITY FILL
DOME MINE FACILITY

BOREHOLE NO: B

STOPE: 552

DRILL: BBU-2

DIP: +15°

DEPTH: 0.0 - 110.0 ft.

LOCATION: Dome 750' Level

DEPTH (ft.)	HOLE DIAMETER (inches)	CORE/SAMPLE RECOVERY	DRILLING METHOD	PRESSURE METER TESTS	COMMENTS
0 - 78.0	3.0	100% (rock)	NQ core barrel	None	Full rock recovery
78.0	Accessed Mine Fill				
78.0 - 81.0	3.0	0%	NQ core barrel	None	Advanced core barrel with water - mine fill broken up & washed out.
81.0 - 86.5	±3.1	100%	Serrated NQ rod	None	±200 rpm - light feed - no water sample totally disturbed
86.5 - 92.0	±3.1	80%	Serrated NQ rod	None	±200 rpm - light feed - no water - sample totally disturbed
92.0 - 100.0	±3.1	60%	Serrated NQ rod	None	±100 rpm - fast fee no water (void btwn 94.8' to 97.8') sample totally disturbed
100.0 - 110.0	±3.1	55%	Serrated NQ rod	None	±100 rpm - medium feed - no water - sample totally disturbed
110.0	End of Borehole				

Remarks:

- Mine fill core diameter 2.20 inches
- Core samples disturbed during drilling and during removal from casing.
- Driller cannot maintain constant feed and rpm.
- Consistency of material variable during drilling (i.e., loose to compact, moisture content varying, etc.)
- Probex pressuremeter tests not performed

BOREHOLE LOG
HIGH DENSITY FILL
DOME MINE FACILITY

BOREHOLE NO: C

STOPE: 552

DRILL: BBU-2

DIP: -10°

DEPTH: 0 - 96.0 ft.

LOCATION: Dome 750' Level

DEPTH (ft.)	HOLE DIAMETER (inches)	CORE/SAMPLE RECOVERY	DRILLING METHOD	PRESSURE METER TESTS	COMMENTS
0 - 88.0	3.0	100% (rock)	NQ core barrel	None	100% rock core recovery, water loss at 85.0', probable mine fill
88.0	Assessed Mine Fill				
88.0 - 96.0	±3.1	45%	Serrated NQ rod	None	100 rpm, medium feed, no water, sample totally disturbed
96.0	End of Borehole				

Remarks:

- Sides of mine fill "caving".
- Mine fill sample disturbed by drilling and removal from casing.
- Driller cannot maintain constant rpm and feed.
- Probex pressuremeter tests not performed.

BOREHOLE LOG
HIGH DENSITY FILL
DOME MINE FACILITY

BOREHOLE NO: 1

STOPE: 552

DRILL: Portable JKS

DIP: +60°

DEPTH: 0 - 15.0 ft.

LOCATION: Dome 750' Level

DEPTH (ft.)	HOLE DIAMETER (inches)	SAMPLE RECOVERY	DRILLING METHOD	PRESSURE METER TESTS	COMMENTS
0 - 5.0	3.25	N/A	solid augers	yes	(CANMET pressuremeter)
5.0	End of Borehole				

Remarks:

- Auger samples secured for moisture content determinatons.
- Augers advanced for pressuremeter tests. Hole had to be "flushed" slightly with air and water to remove cuttings.
- Pressuremeter tests performed by CANMET representative. Installation of pressuremeter difficult due to weight and length of probe.

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(v) Trow

BOREHOLE LOG
HIGH DENSITY FILL
DOME MINE FACILITY

BOREHOLE NO: 2

STOPE: 552

DRILL: Portable JKS

DIP: +80°

DEPTH: 0 - 16.0 ft.

LOCATION: Dome 750' Level

DEPTH (ft.)	HOLE DIAMETER (inches)	SAMPLE RECOVERY	DRILLING METHOD	PRESSURE METER TESTS	COMMENTS
0 - 16.0	±3.1 - 3.3	zero	NW core barrel	None	Air & water "flushing" used
16.0	End of Borehole				

Remarks:

- Variation of feed, rpm and air and water flushing techniques used during drilling.
- No pressuremeter tests performed.

BOREHOLE LOG
HIGH DENSITY FILL
DOME MINE FACILITY

BOREHOLE NO: 3

STOPE: 552

DRILL: Portable JKS

DIP: +80°

DEPTH: 0 - 46.0 ft.

LOCATION: Dome 750' Level

DEPTH (ft.)	HOLE DIAMETER (inches)	SAMPLE RECOVERY	DRILLING METHOD	PRESSURE METER TESTS	COMMENTS
0 - 46.0	3.0	N/A	augers	yes	No samples recovered. (Hole drilled for instrumentation purposes.)
46.0	End of Borehole				

Remarks:

- Pressuremeter tests performed at 21', 17.7', 14.4' and 11.2' using Texam pressuremeter.
- Dome Mines pressure cell installed.

BOREHOLE LOG
HIGH DENSITY FILL
DOME MINE FACILITY

BOREHOLE NO: 4

STOPE: 552

DRILL: Portable JKS

DIP: +80°

DEPTH: 0 - 29.0 ft.

LOCATION: Dome 750' Level

DEPTH (ft.)	HOLE DIAMETER (inches)	SAMPLE RECOVERY	DRILLING METHOD	PRESSURE METER TESTS	COMMENTS
0 - 10.0	3.6	10%	NW casing	None	Flushing with air
10.0 - 29.0	3.1	zero	solid augers	None	Intended for pressure meter testing
29.0	End of Borehole (Hole abandoned - augers seized in hole)				

Remarks:

- Air pressure disintegrating mine fill samples during drilling to 10.0' depth.
- Augers advanced to 29.0' and encountered steel object at 27.5' depth. Augers "seized" in hole and cannot be removed - hole abandoned.
- No pressuremeter tests performed.

BOREHOLE LOG
HIGH DENSITY FILL
DOME MINE FACILITY

BOREHOLE NO: 5

STOPE: 552

DRILL: Portable JKS

DIP: +6.0°

DEPTH: 0 - 29.0 ft.

LOCATION: Dome 750' Level

DEPTH (ft.)	HOLE DIAMETER (inches)	SAMPLE RECOVERY	DRILLING METHOD	PRESSURE METER TESTS	COMMENTS
0 - 3.0	3.1-3.7	10%	NW core barrel	None	Core barrel advanced using air flushing & barrel "blocking" frequently, little sample return
3.0 - 6.0	3.0-3.7	zero	BW core barrel	None	Core barrel advanced using water "flushing", no core recovery
6.0 - 29.0	3.1-3.4	zero	NW core barrel	None	Water "flushing", borehole alignment deflecting due to water flow & wash out of material
29.0	End of Borehole				

Remarks:

- Use of air and water with core barrels at variable feeds and rpm's not successful.
- Hole diameter and alignment fluctuating due to removal of mine fill with air and water flow.
- Hole size and alignment outside limits for pressuremeter tolerances.
- No pressuremeter tests performed.

BOREHOLE LOG
HIGH DENSITY FILL
DOME MINE FACILITY

BOREHOLE NO: 6

STOPE: 552

DRILL: Portable JKS

DIP: +8.0°

DEPTH: 0 - 21.0 ft.

LOCATION: Dome 750' Level

DEPTH (ft.)	HOLE DIAMETER (inches)	SAMPLE RECOVERY	DRILLING METHOD	PRESSURE METER TESTS	COMMENTS
0 - 21.0	3.0 - 3.2	N/A	solid augers	None	Hole advanced to check variation of hole diameters
21.0	End of Borehole				

Remarks:

- Varying speeds and rpm used on augers for hole advancement.
- Auger head removed at intervals to ascertain effect on varying hole dimensions and cutting removal.
- No pressuremeter tests performed.

S871465R

(x) Trow

BOREHOLE LOG
HIGH DENSITY FILL
DOME MINE FACILITY

BOREHOLE NO: 7

STOPE: 552

DRILL: Portable JKS

DIP: +4°

DEPTH: 0 - 20.5 ft.

LOCATION: Dome 750' Level

DEPTH (ft.)	HOLE DIAMETER (inches)	SAMPLE RECOVERY	DRILLING METHOD	PRESSURE METER TESTS	COMMENTS
0 - 2.0	±2.74	80%	adapted sampler	yes*	
2.0 - 3.6	±2.75	90%	adapted sampler		
3.6 - 5.5	±2.75	100%	adapted sampler		
5.5 - 6.4	±2.75	100%	adapted sampler		
6.4	Could not advance sampler - dense mine fill - no cutting head on sampler.				
6.4 - 20.5	Advanced solid augers for clear hole for pressuremeter tests.				
20.5	End of Borehole				

Remarks:

- Adapted sampler obtained samples in relatively loose material but unable to penetrate denser layers.
- Pressuremeter tests performed at depths of 11.2', 14.4', 17.7' and 21.0'. using Texam pressuremeter.
- 0.0 to 9.5 ft. portion of hole loose, caving and disturbed by drilling.

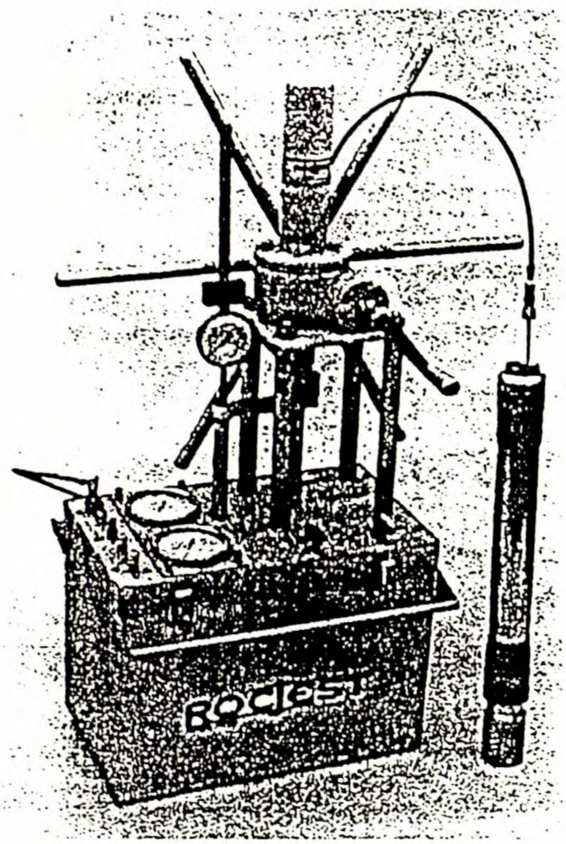
*Test results inconsistent

Trow

APPENDIX 2

DETAILS OF TEXAM PRESSUREMETER
CORRECTED PRESSUREMETER CURVES

PRESSUREMETER
Model TEXAM®



FEATURES

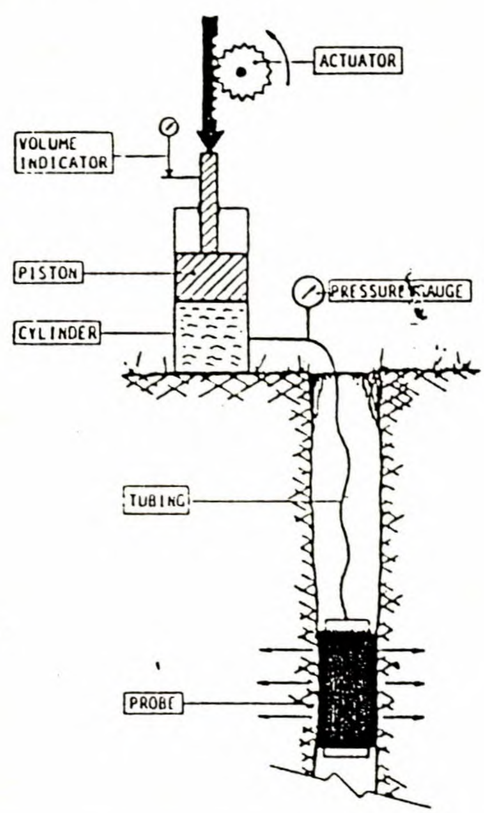
- Rugged construction
- Very simple to operate
- Measurement of the total volumetric change of the cavity to avoid possible errors related to measurement of the variations of diameter in one plane
- Controlled rate of deformation
- Easy cyclic testing
- Optional equipment is available for:
  — Creep testing
  — Self boring
  — Automation

APPLICATIONS

The TEXAM® pressuremeter is a reliable and economical instrument for the evaluation of most ground engineering problems.

The well-proven method developed by Louis Menard is utilized to interpret the test results for calculation of:

- **BEARING CAPACITY** of shallow and deep foundations
- **SETTLEMENT** of all types of foundations
- **DEFORMATION** of laterally loaded piles and sheet piles
- **RESISTANCE** of anchors



DESCRIPTION

The TEXAM® pressuremeter is a borehole device used to run in-situ loading tests at various depths on a routine basis. It is a very simple and rugged instrument consisting of:

THE PROBE — A cylindral hollow body fitted with inflatable shealth.

THE CONTROL UNIT —

— A metal case which houses a cylinder with piston, two pressure gauges for low and maximum pressure tests, a connector for an auxiliary pressure gauge, and the control valves.

— A manual actuator to operate the piston.

THE TUBING — A high pressure single conduit fitted with a shut-off quick connect to keep the probe and tubing saturated.

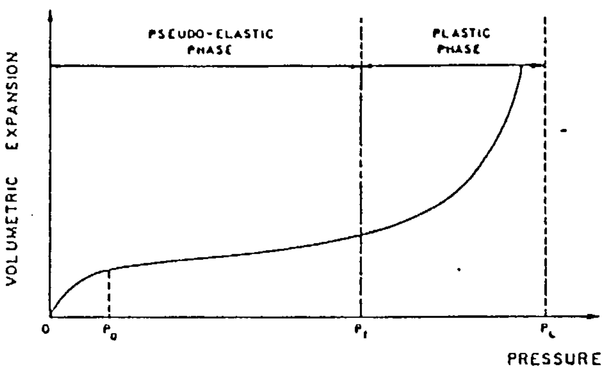
ROCTEST

ROCTEST LTÉE/LTD.
665 PINE, ST-LAMBERT (MONTREAL), CANADA J4P 2P4
TEL.: (514) 465-1113 - TELEX: 055-61134 - CABLE: TESTROC

TEST PROCEDURE

The probe is placed at the test depth in a pre-drilled borehole obtained by a method adapted to the soil conditions: augering, rotation with drag bit and bentonite, shelby tube driving, etc. In granular soils below the water table, the probe can be driven directly within a slotted casing.
The test is run either with a constant rate of deformation by using a uniform rate of rotation of the actuator or with equal increments of pressure as for the Menard pressuremeter test.

TEST RESULTS



An in-situ stress-strain curve is obtained by plotting the injected volume versus pressure

— The "limit pressure = P_L " is the pressure at which failure occurs and it directly reflects the bearing capacity:

$$Qa = \frac{C}{F} P_L$$

— The modulus of deformation E is used to calculate settlement and is given by:

$$E = \frac{(1+\mu)\, 2V \quad \Delta P}{\Delta V}$$

ACCESSORIES

- Slotted casing assembly for direct driving of the AX size probe in granular soils below the water table
- Self boring conversion kit for the NX size probe, for the fine gravel-free soils
- Creep test kit for long term testing at constant pressure
- Automation kit for recording or direct plotting of the pressuremeter curve

SPECIFICATIONS

CONTROL UNIT

Dimensions	L = 52 cm
	W = 31 cm
	H = 46 cm
Weight	30 kg
Max working pressure	10 000 kPa (1500 PSI)
Actuator capacity	10 tons
Actuator weight	28 kg

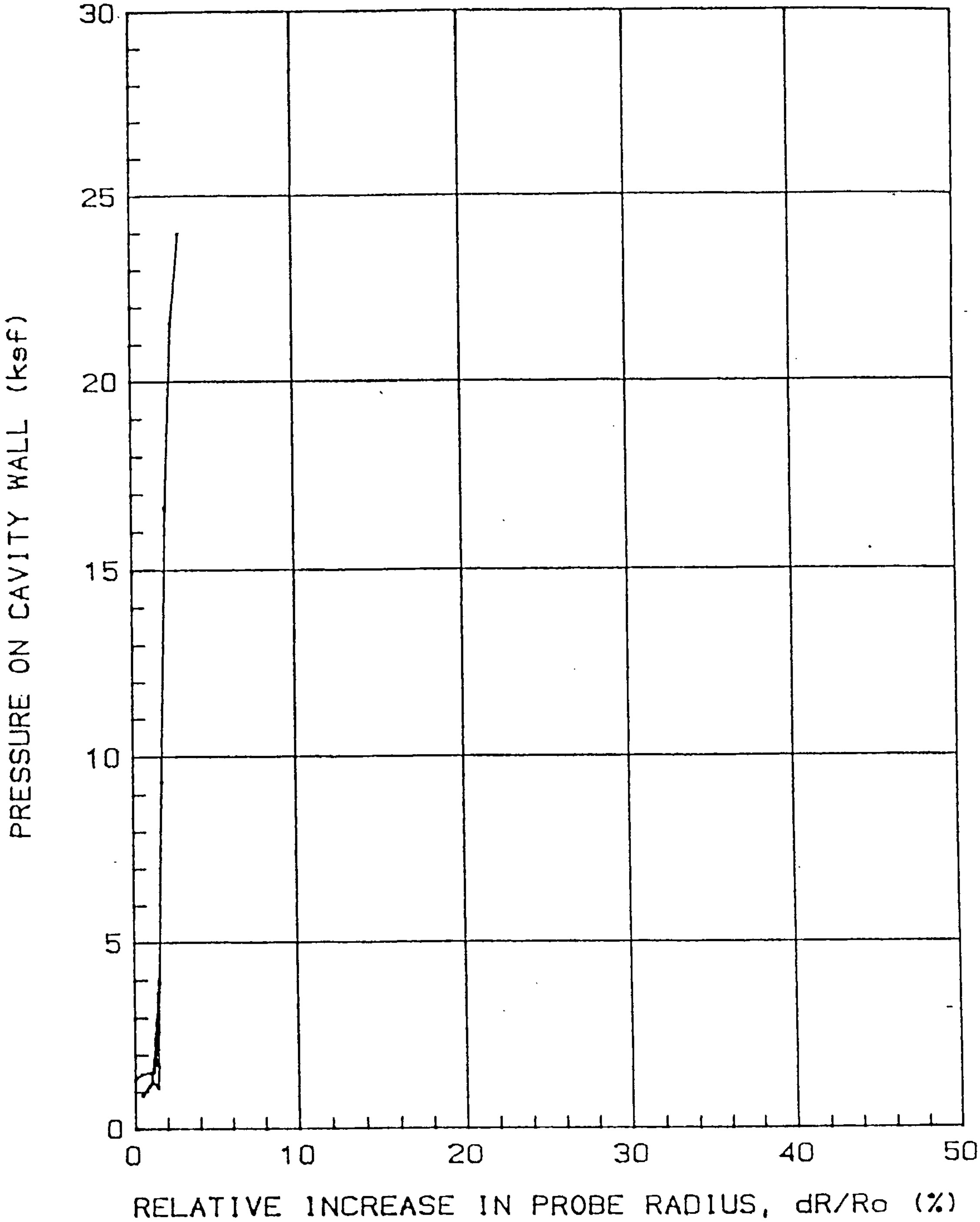
PROBES

Diameter:	44mm (AX)	60mm (BX)	70mm (NX)
Length:	84 cm	70 cm	70 cm
Weight:	4.5 kg	4.3 kg	6.4 kg

ROCTEST

ROCTEST LTÉE/LTD.
665 PINE, ST-LAMBERT (MONTREAL) CANADA J4P 2P4
TEL.: (514) 465-1113 • TELEX: 055-61134 • CABLE: TESTROC

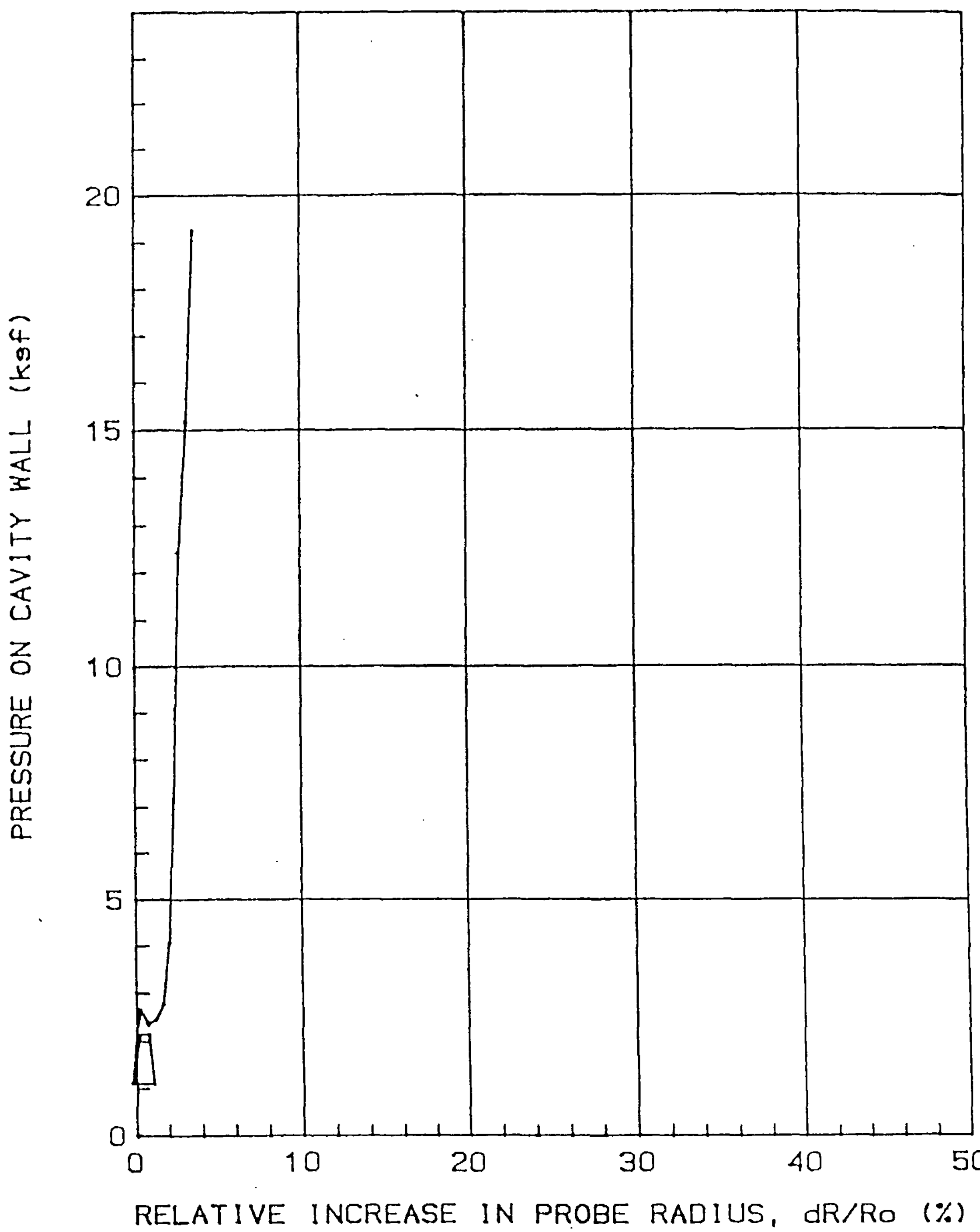
CORRECTED PRESSUREMETER CURVE



TROW ONTARIO LTD., SUDBURY		
Project: S871465R	Client: Dome Mines Limited	Date: 08-18-1987
Borehole No.: 3	Depth: 21 ft.	Test No.: 1
Location of Test:		Borehole Angle: 0

Summary of Strength Parameters		
	Po = 1.4 ksf	Eo = 882 ksf
	Pl = 25 ksf	Er = 3447 ksf
	Pl* = 23.6 ksf	Eo/Pl* = 37.3

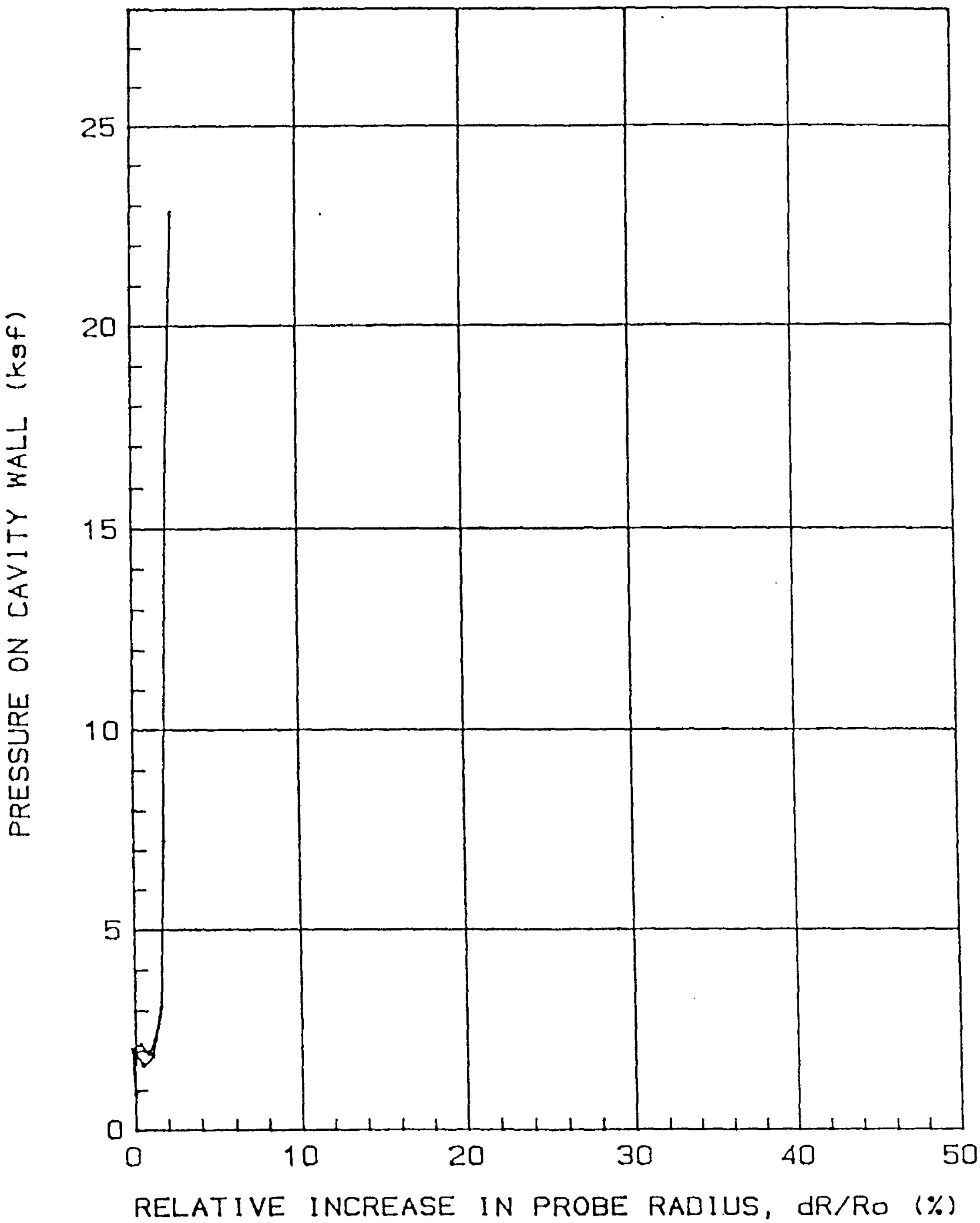
CORRECTED PRESSUREMETER CURVE



TROW ONTARIO LTD., SUDBURY		
Project: S871465R	Client: Dome Mines Limited	Date: 08-18-1987
Borehole No.: 3	Depth: 17.7 ft.	Test No.: 2
Location of Test:		Borehole Angle: 0

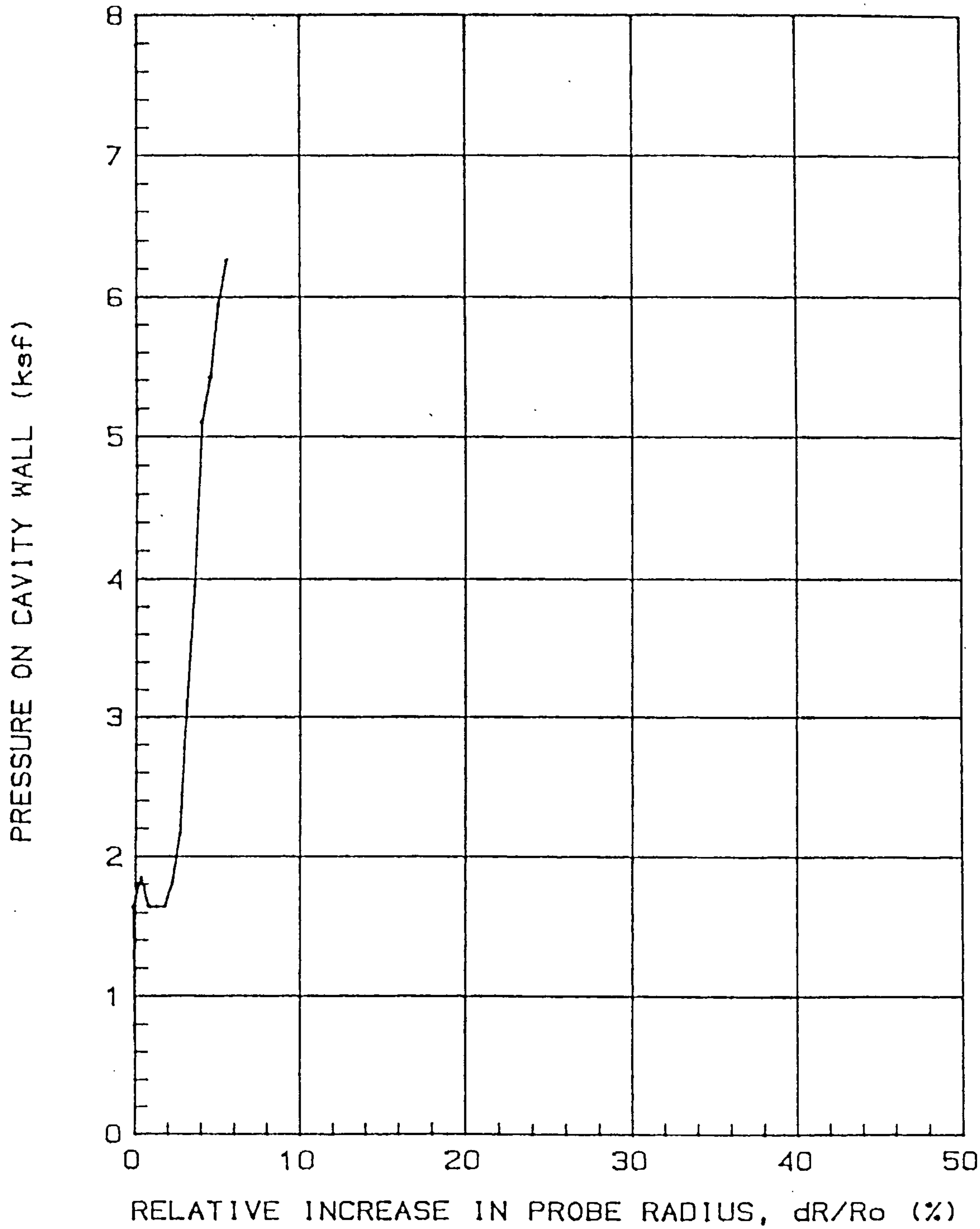
Summary of Strength Parameters		
	Po = 1.2 ksf	Eo = 1663 ksf
	Pl = ksf	Er = ksf
	Pl* = ksf	Eo/Pl* =

CORRECTED PRESSUREMETER CURVE



TROW ONTARIO LTD., SUDBURY		
Project: S871465R	Client: Dome Mines Limited	Date: 08-18-1987
Borehole No.: 3	Depth: 14.4 ft.	Test No.: 3
Location of Test:		Borehole Angle: 0
Summary of Strength Parameters	Po = 1 ksf Pl = 30 ksf Pl* = 29 ksf	Eo = 2289 ksf Er = 3707 ksf Eo/Pl* = 78.9

CORRECTED PRESSUREMETER CURVE



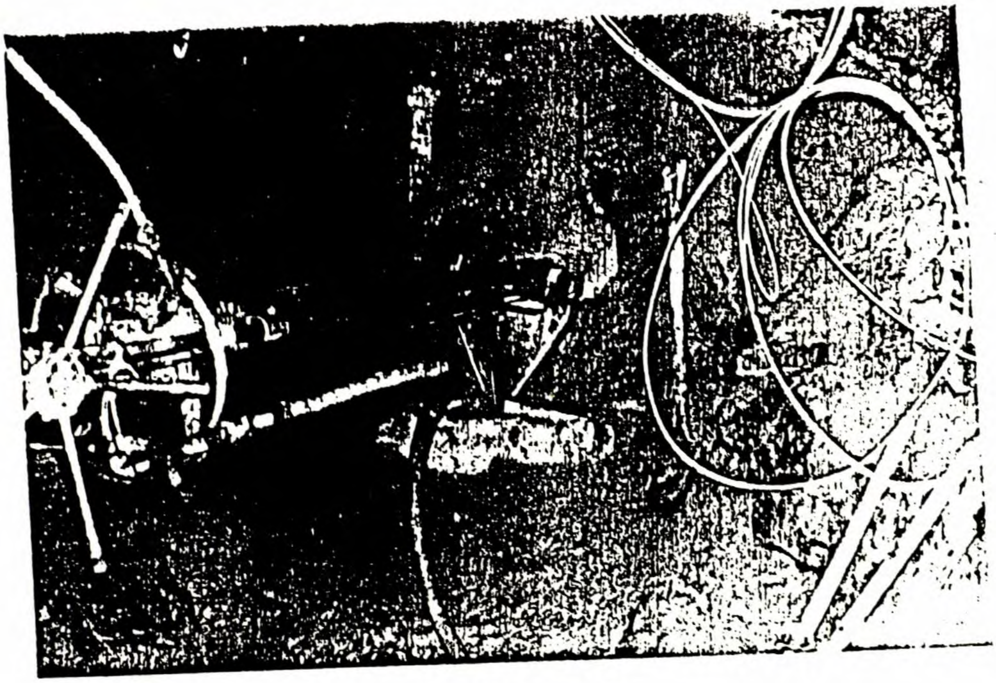
TROW ONTARIO LTD., SUDBURY		
Project: S871465R	Client: Dome Mines Limited	Date: 08-18-1987
Borehole No.: 3	Depth: 11.2 ft.	Test No.: 4
Location of Test:		Borehole Angle: 0
Summary of Strength Parameters	Po = .8 ksf Pl = 7 ksf Pl* = 6.2 ksf	Eo = 425 ksf Er = 310 ksf Eo/Pl* = 68.5

Trow

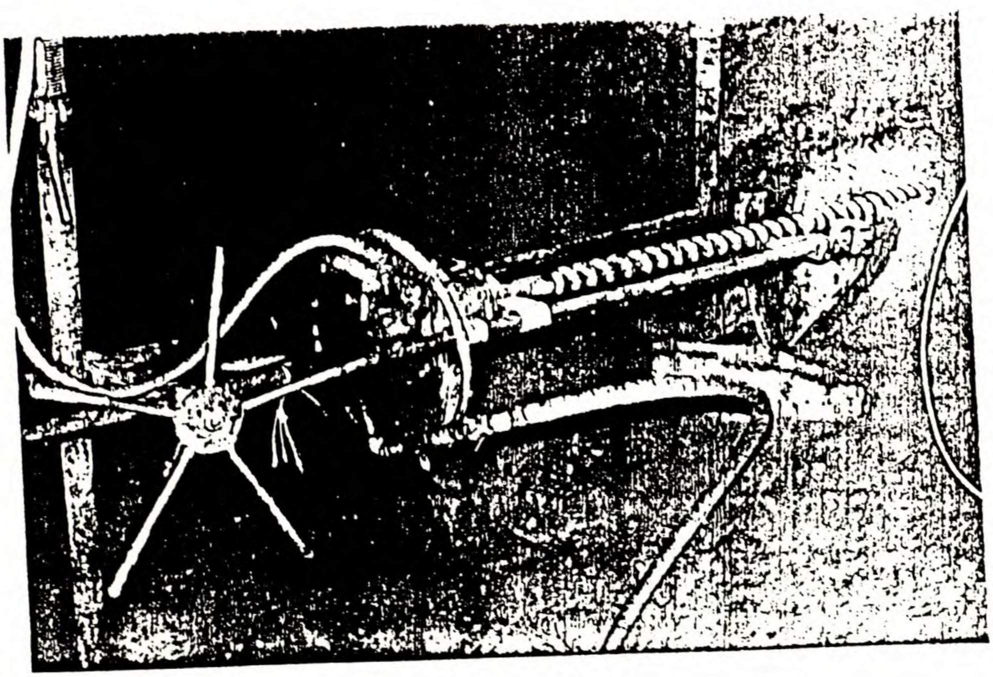
APPENDIX 3

PHOTOGRAPHS

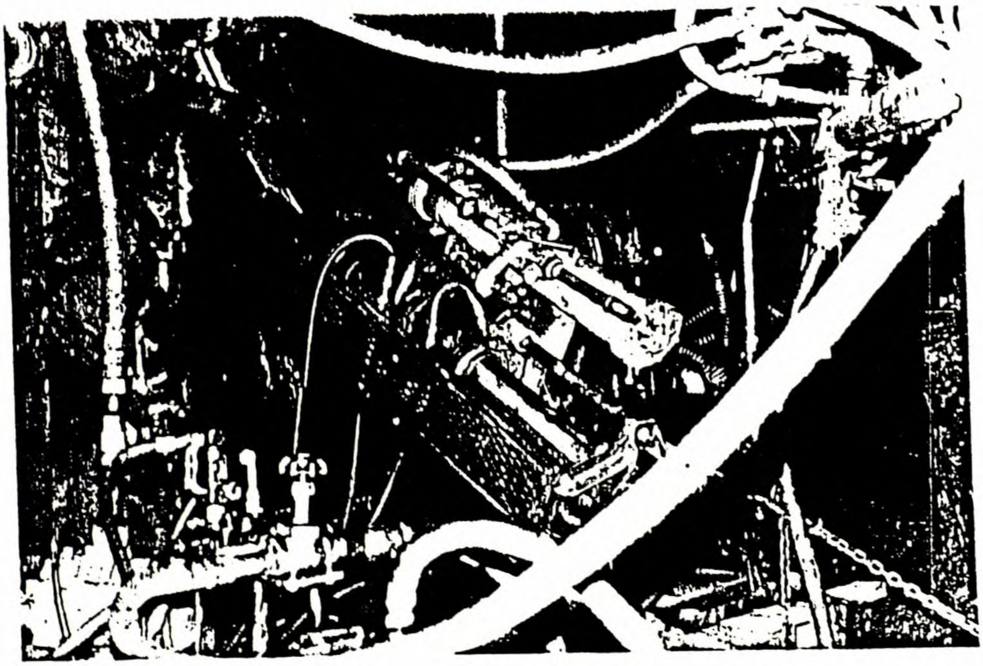
S871465R



PHOTOGRAPH #1
PORTABLE DRILL WITH A.W. CORE BARREL



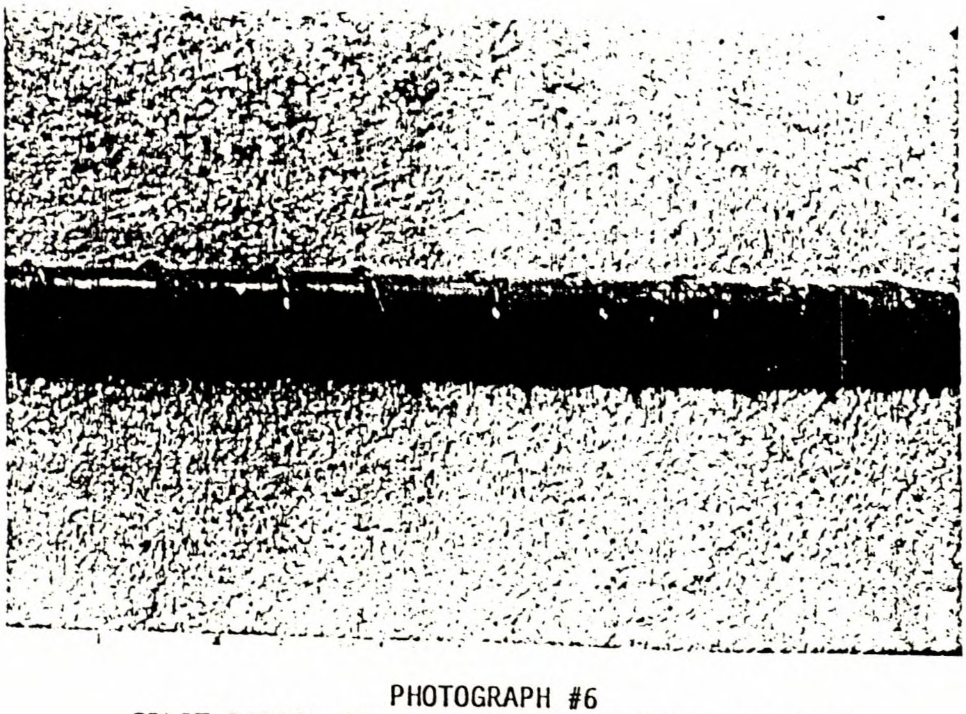
PHOTOGRAPH #2
PORTABLE DRILL WITH FLIGHT AUGER



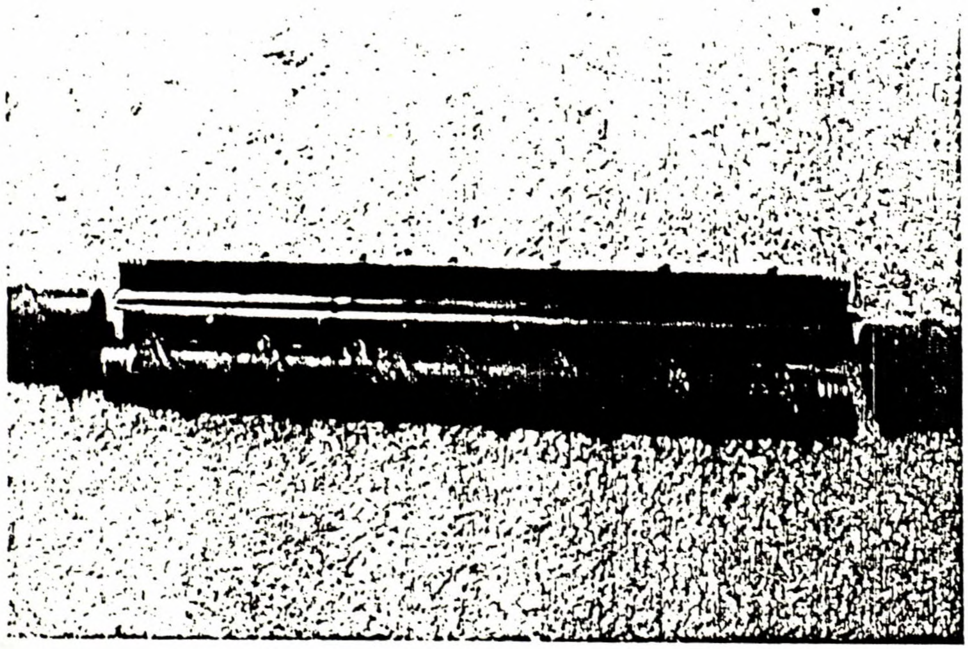
PHOTOGRAPH #3
BBU-2 WITH HYDRAULIC HEAD

PHOTOGRAPH #4
SLOUGHING & DISTURBANCE IN BOREHOLE

PHOTOGRAPH #5
SERRATED NQ DRILL ROD



PHOTOGRAPH #6
SPLIT BARREL SAMPLES WITH CONTINUOUS FLIGHTS

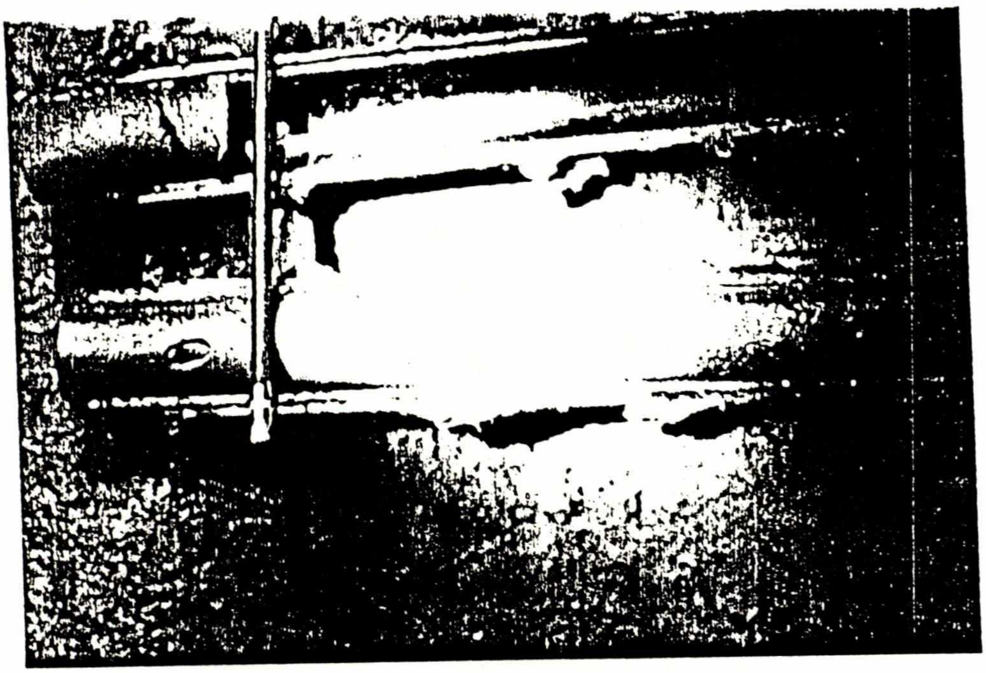


PHOTOGRAPH #7
SPLIT BARREL SAMPLES - UNASSEMBLED

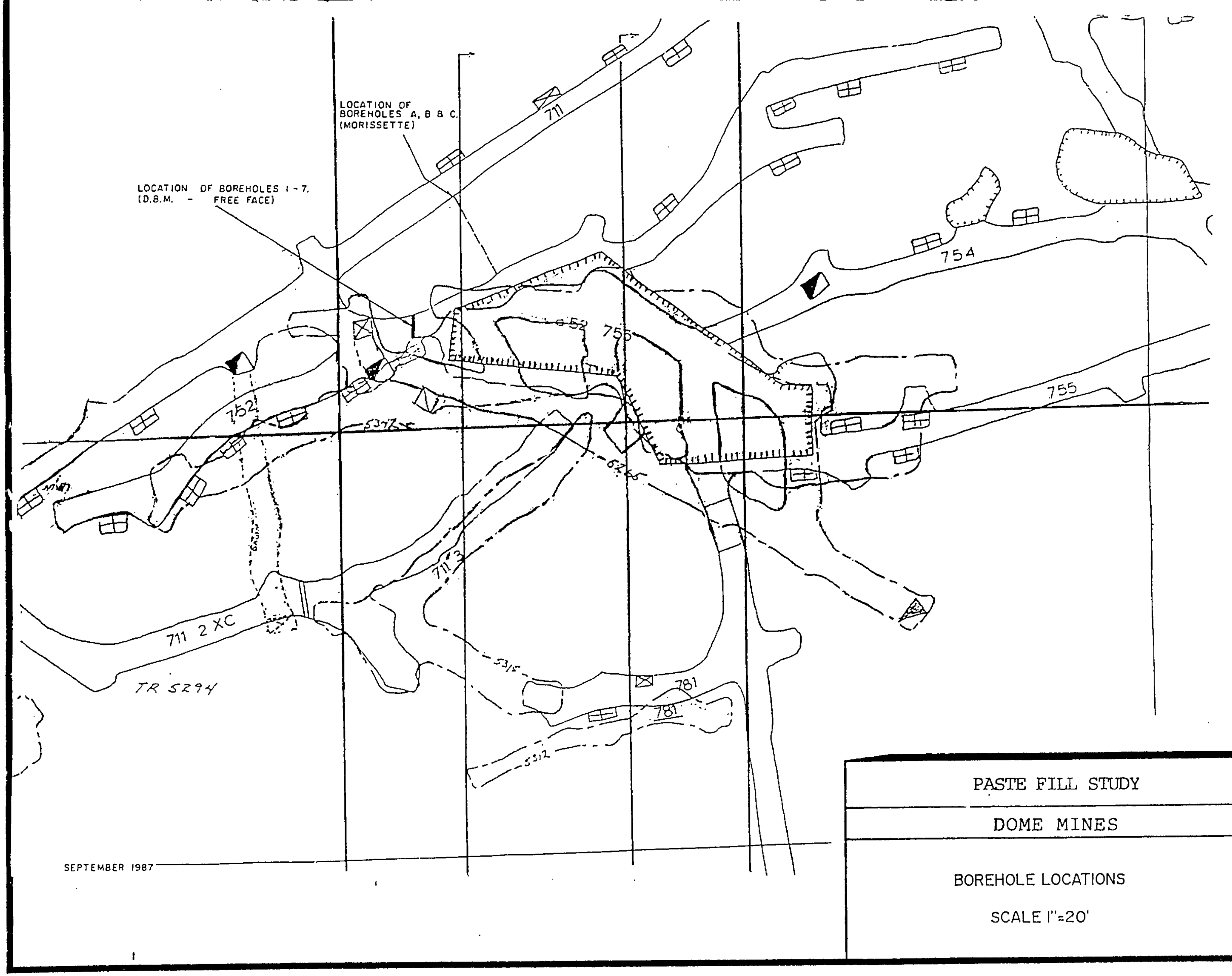
PHOTOGRAPH #8
CLOSE-UP OF CONTINUOUS FLIGHTS

S861465R

 Trow



PHOTOGRAPH #9
CORE RECOVERY WITH SPLIT BARREL SAMPLES



PASTE FILL STUDY

DOME MINES

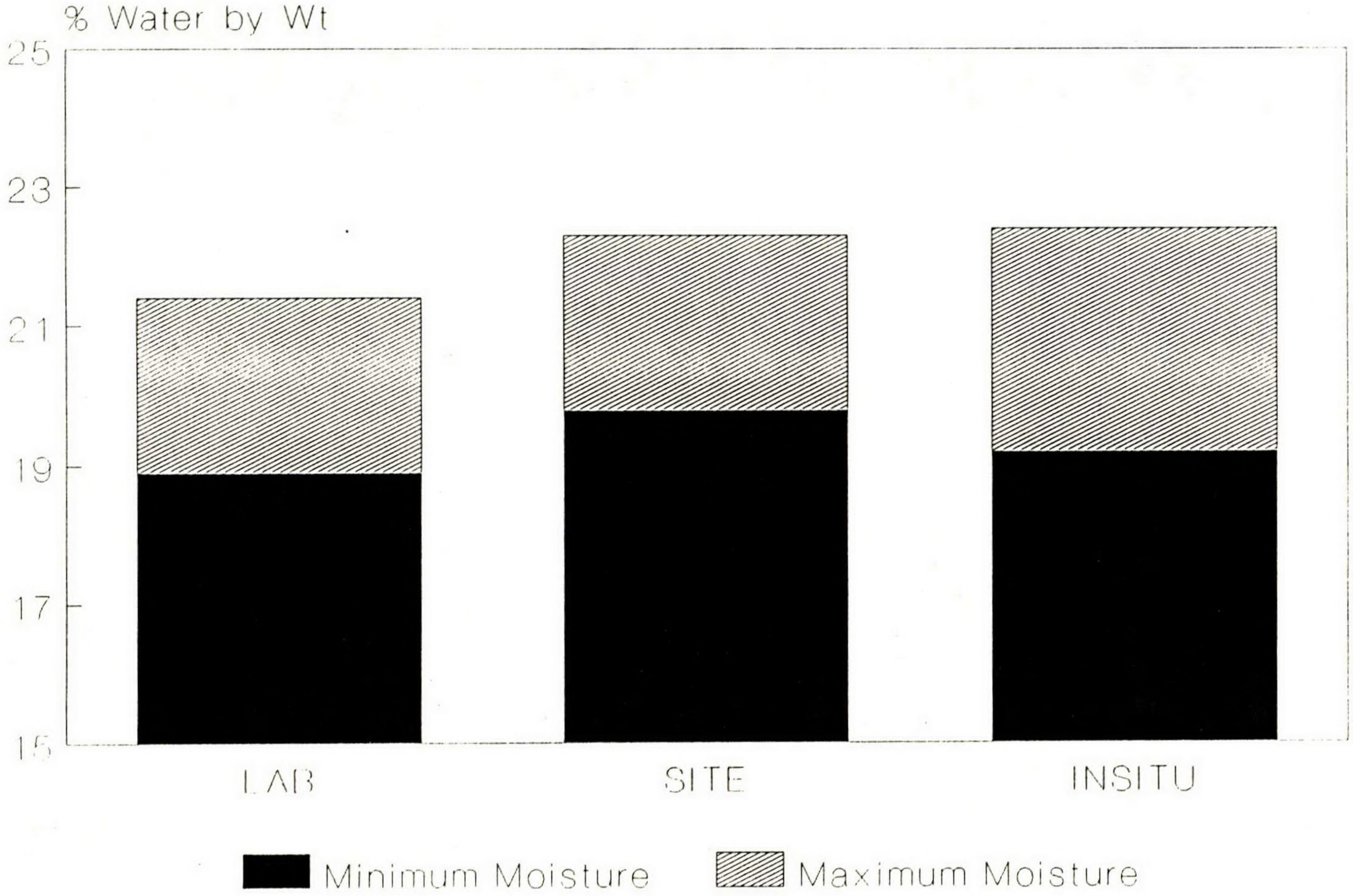
BOREHOLE LOCATIONS

SCALE 1"=20'

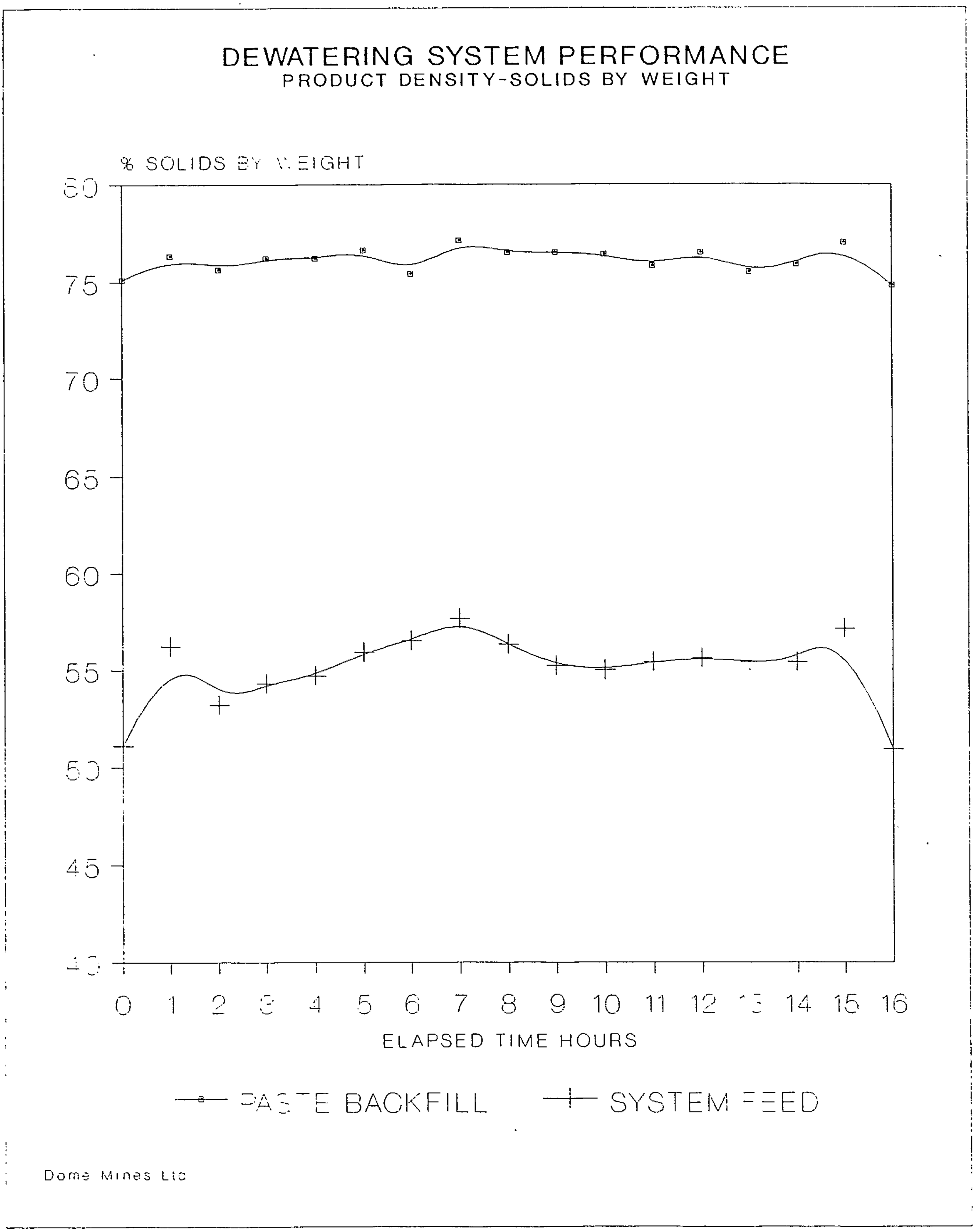
APPENDIX II

DEWATERING SYSTEM QUALITY CONTROL

CONSOLIDATED PASTE BACKFILL
MOISTURE CONTENT VARIATIONS



Dome Mines Ltd



DEWATERING SYSTEM PERFORMANCE
PRODUCT DENSITY-SOLIDS BY WEIGHT
% SOLIDS BY WEIGHT
80
75
70
65
60
55
50
45
40
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
ELAPSED TIME HOURS
PASTE BACKFILL
SYSTEM FEED
Dome Mines Ltd

May 21 & 22

TAILSPINNER DAILY LOG SHEET

TIME

SH TIM

ATOR J. Brecken 6/B

NB: Record time, duration and reason for shutdowns.

IME	SPEED	FLOW RATE	FEED MARCY	FEED SAMPLE NUMBER	FEED CONC	OVERFLOW MARCY	OVERFLOW SAMPLE NUMBER	OVERFLOW CONC	UNDERFLOW SAMPLE NUMBER	UNDERFLOW CONC	CEMENT CAR NO.	CEMENT BAG NO.
22:00	1800	73	58			33.5						
15		73	58			33.5						
30		73	58			33.5						
45		73	58			34				75.5		
23:00	1800	73	58.5	202	55.3	34	203	30.8	204	335.65		
15		73	58			33						
30		73	57			33						
45		73	57			32.5						
24:00	1800	73	57			32						
15		72	55			30						
30		72	53			29						
45	1450	72	53			35				74.5		
1:00	1500	72	53	205	51.3	33.5	206	32.8	207	370.52		
15		72	53.5			33.5						
30		72	54			34						
45		72	55			36						
2:00	1500	72	56			40						
15	1700	72	57			35						
30	1750	72	57.5			34.5					150	145
45	1750	73	56			36				76.5		
3:00	1750	73	59	208	55.0	38	209	36.1	210	311.56		
15	1800	73	59			38						
30		73	58.5			36.5						
45		73	58.5			34						
4:00	1800	73	58			34						
15		73	57			34						
30		73	57			34						
45		73	57.5			34						
5:00	1860	73	57.5	211	54.5	33	212	32.3	213	75.7		
15		73	57.5			33						
30		73	57.5			33						
45		73	57.5			33						
6:00	1800											

APPENDIX III

ACCURASSAY LABORATORIES LIMITED
REPORT ON CEMENT CONTENT AND TAILINGS

ACCURASSAY
Laboratories Ltd.

DEVELOPMENT OF A RELIABLE & RAPID METHOD FOR THE DETERMINATION OF THE CEMENT CONTENT OF UNDERGROUND FILL USED AT DOME MINES, PORCUPINE, ONT.

AUTHOR: Dr. George Duncan, President,
Accurassay Laboratories Ltd.,
Box 604, 3 Industrial Dr.,
Kirkland Lake,
Ont. P2N 3J5 Tel: (705) 567 6343

SYNOPSIS

Several different procedures were checked to det rmine their reliability as methods for cement-content analysis in underground fill. These included atomic absoprtion, spectrophotometry and titrimetric analysis. Only one was found which combined reliability with rapidity and this is essentially the titrimetric procedure described by Wiseman[1] at Falconbridge Nickel Mines, Ont.

(1) See Appendix 2, on page 5

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Laboratories Ltd.

INTRODUCTION

The current method for cement in underfill analyses involves a gravimetric procedure utilising a solution of salicylic acid in methanol to extract the calcium from the sample followed by filtration, drying & weighing of the residue. Although accurate, this method can be very time-consuming since the sintered-glass crucibles often become plugged with the fines from the cement leading to inordinately long analysis times. Thus a more rapid & reliable method was sought.

Four different approaches were taken:

(1) Contact Canada Cement Lafarge to determine what current methods are available.

(2) See if there is a correlation between the iron extracted by the salicylic acid-methanol procedure and the cement content (the iron reacts with the salicylic acid to produce an intense purple colour in the supernatant solution).

(3) See if there is a correlation between the purple colour and the cement content.

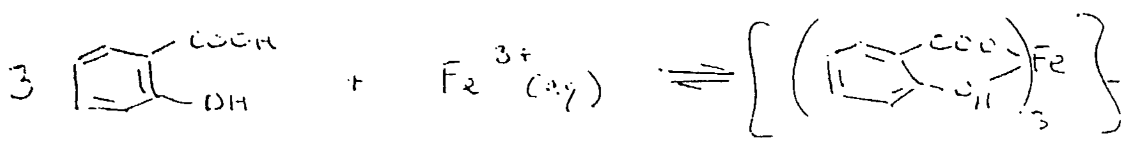
(4) Check the Wiseman[1] method as to its suitability for Dome Mines underfill.

(1) Canada Cement Lafarge.

Several people were contacted and eventually a method was obtained from Mr. Paul Lehoux of the Montreal plant. The method used by him is another gravimetric procedure which determines sulphate content and relates that to the cement content but the method is even longer than the gravimetric procedure mentioned above and so this approach was abandoned.

(2) Iron Determination.

When running the salicylic acid-methanol method it was noticed that an intense purple colour formed characteristic of the iron-salicylate complex:



Thus it was postulated that iron, along with calcium was being extracted and that this iron may be quantifiable by atomic absorption spectroscopy. No elaborate filtration step would be necessary provided that any fines remaining

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could pass through the burner system.

Results. Readings on the atomic absorption instrument were very non-reproducible since the high concentration of salicylic acid in the solution tended to plug the nebulizer chamber and so this approach was abandoned.

(3) Colorimetric Procedure

This follows method (2) above to the stage where the purple filtrate is obtained. At this point a sample is taken and measured at its wavelength of maximum absorption (found to be 510nm) in a spectrophotometer. Once again results from this method were inconclusive since the blanks absorbed almost as strongly as the samples.

(4) Wiseman Method

A copy of the method used at Falconbridge Nickel was obtained from the author. Essentially, this is an ammonium chloride leach of the underfill to remove the calcium from the cement and to titrate the calcium with EDTA. However, in order to find the calcium leached from the cement, blanks must be run to determine how much calcium is leached from the raw tailings and also how much calcium is present in the pure cement. In the Falconbridge situation, both these latter variables change from batch to batch and it can be assumed that the same will be found in the Dome Mines situation. THEREFORE, IT IS ESSENTIAL THAT FOR AN ACCURATE RESULT TO BE FOUND FOR ANY UNDERFILL SAMPLE, A SAMPLE OF THE RAW TAILINGS AND PURE CEMENT ALSO BE RUN AT THE SAME TIME. Several sample were run by this method and it appeared to work well with only minor modifications. Analysis times are very much lower than the older gravimetric procedure and have the extra advantage that checks can be run on the solution produced without the need to start from the beginning.

Results

Sample	%Ca Found	Ratio Tailings/Cement	
		Theoret.	Found
Standard Underfill 1	6.55	19:1	20.7:1
Standard Underfill II	8.39	9:1	9.9:1
Standard Underfill III	11.03	4:1	5.4:1
Raw Tailings (Blank aver. of 4)	4.69		
Pure Cement (Aver. of 4)	45.1		

A sample previously run by the older gravimetric procedure was re-run using the titrimetric procedure to see how the values compared. Results are given below:

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Sample	Ratio Found	
	Gravimetric	Titrimetric
Dome Underfill UF-311-1055	4.19:1	4.38:1 (average of 2)

If we assume that there has been no change either in the blank value or the pure cement value in the period between first running this sample gravimetrically and then re-running it titrimetrically (approx. 3 months), the results agree well between the two methods.

Modification to the Wiseman Method

The method requires only slight modification to be suitable for Dome Mines underfill and this takes place in the last stage of the analysis. The author uses a direct EDTA titration of the leached calcium but recommends the addition of 1.0ml of standard magnesium solution to help sharpen the rather slow end-point. . This adds an extra step and makes for a slower titration. To circumvent this problem it is recommended that a "back-titration" be performed in which the sample solution to be titrated is treated with an excess of EDTA and the unreacted portion of the EDTA is titrated with standard magnesium. The calcium leached from the sample is found from the difference between EDTA added and EDTA reacted with the magnesium. The end-point by this method is quite sharp & fast.

Conclusions

The Wiseman method for the determination of cement in underfill works well with Dome Mines samples and is recommended as a replacement for the older gravimetric procedure currently being used. Analysis times for the titrimetric method are approximately 90 minutes compared with several hours (up to 12) for the gravimetric procedure. For larger numbers of samples, the time per analysis could be further reduced to approx 45 min.

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APPENDIX 1

GRAVIMETRIC METHOD FOR THE DETERMINATION OF CEMENT IN DOME MINES UNDERFILL

Reagents: Methyl alcohol (lab or technical grade). This can be purchsed in 4-litre bottles from local hardware stores as methyl hydrate.

Salicylic acid (lab grade).

Extraction solution. Weigh out sufficient salicylic acid to give a concentration of 160g/l in methyl alcohol (each test requires 250ml of this solution).

Apparatus: Sintered glass crucibles (fine porosity), 500ml conical flasks, buchner flasks (500ml).

Method: Accurately weigh out approx. 20g of underfill sample and place in the conical flask. Add 250ml salicylic acid solution and swirl vigorously to mix. Stopper flask and shake for 30 min to complete extraction of the cement. Remove from the shaker and allow to settle for two hours while flask sits at an angle with its neck resting on a 250ml beaker (this allows the supernatant to be filtered with minimal disturbance of the solids). Weigh the sintered-glass crucible and then filter the supernatant liquid under vacuum being careful not to allow any fines to be carried over and plug the sintered glass. Rinse the flask with fresh methyl alcohol several times until no further colour is seen in the alcohol, allowing the fine solids to settle as much as possible between rinsings (this may take several hours). Finally transfer all the solids from the flask to the crucible, using fresh alcohol to wash them through. Dry the solids in an air oven at 100°C, cool and weigh. Repeat the above procedure with a sample of dry, raw tailings to establish a correction to be applied to the test sample. Calculate the ratio of tailings/cement using the following:

$$\text{ratio tailings/cement} = \frac{\text{wt. residue as \% of sample wt.}}{100 - \text{wt. loss found as \% " "}}$$

The weight loss found (expressed as a % of sample weight)should be corrected for the blank.

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APPENDIX 2

IMPROVED ANALYSIS PROCEDURE FOR CEMENT RATIO IN UNDERGROUND FILL.

AMMONIUM CHLORIDE LEACH WITH EDTA FINISH.

REAGENTS

5% w/v ammonium chloride solution, conc. ammonia, sodium chloride: Eriochrome Black T as indicator (grind these two in a 200:1 ratio and store in a glass bottle). Ethylene diamine tetra-acetic acid (EDTA) soln., 0.01M with 3 pellets of sodium hydroxide per litre. Store in a plastic bottle to prevent leaching of Ca from glass. 0.01M Magnesium solution prepared from analar grade magnesium acetate. Use this to standardise the EDTA and for subsequent back-titrations.

APPARATUS

No special apparatus is required. USE ADEQUATE VENTILATION WITH CYANIDE.

SAMPLE PREPARATION

Grinding of samples is not recommended but if necessary, grind to no more than -40 to -100 mesh, otherwise extra calcium may be leached from samples.

PROCEDURE

For underfill samples weigh approx. 1.0g quantities, for pure cement, weigh approx. 0.5g samples and for raw tailings, weigh approx. 2g samples into 400ml beakers.

Add about 125ml of the 5% ammonium chloride solution and swirl to mix.

Heat strongly on a hot plate to produce a vigorous, rolling boil for about 30 min, maintaining the volume of ammonium chloride at over 100ml.

Cool solution using cold-water(distilled) rinses to wash down the walls of the beaker and then filter or decant into 200ml volumetric flasks. Small amounts of residue in the solution will not affect the titration. Top to the mark when cool.

Use 5ml aliquots for cement and 10 ml for all others in 250ml beakers. Pipet in 10ml standard EDTA solution and add approx. 5ml ammonia followed by a few crystal of sodium cyanide. (NOTE THE ORDER!). Add a pinch of indicator. Titrate the blue-colored solution to a purple end-point.

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If the end-point is poor, add another pinch of indicator just before the end-point. Alternatively, calcon indicator can be used.

CALCULATIONS

#mfw Calcium = #mfw EDTA added − #mfw Mg^{2+} required to reach end-point

$= \text{vol. EDTA} \times M_{EDTA} - \text{Vol. } Mg^{2+} \times M_{Mg^{2+}}$ (vols. in mls)

Therefore, wt. Calcium in sample = $\#mfw \times 40 \times \frac{\text{sample vol.}}{\text{aliquot vol.}}$ (ans. in mg)

" % Ca in sample = $\frac{\text{Wt Ca in mg}}{\text{sample wt in mg}} \times \frac{100}{1}$

Now,

let x = % Ca in cement

y = % Ca in raw tailings

z = % Ca in sample

then,

if a = weight fraction of cement & b = weight fraction of tailings

$a + b = 1$ and b/a is the ratio of tailings/cement

to find b/a:

$$ax + by = z$$

Therefore,

$$ax + (1-a)y = z$$

$$a(x - y) = z - y$$

$$a = \frac{z - y}{x - y}$$

Thus,

$$b/a = \frac{(1-a)}{a} = \frac{1 - \frac{z-y}{x-y}}{\frac{z-y}{x-y}}$$

SAMPLING PROCEDURES

With each sample submitted for analysis, also include a sample of the cement used and the tailings used. If samples are wet, store in plastic bags.

APPENDIX IV

STATE-OF-THE-ART REVIEW ON DEWATERING SCHEMES FOR MINE BACKFILL BY FALCONBRIDGE LIMITED

Note: This report is available through Canmet