SOIL AND FOUNDATION INVESTIGATION REPORT

BOOTH TOWER PURGE GAS BLOWER PLANT

YARD PIPING PLANT - EL PASO, TEXAS

PICKERING LABORATORIES, INC.

SERGENT, HAUSKINS & BECKWITH

[redacted]

SOIL MECHANICS

DICKINSON LABORATORIES, INC.

ASSAYERS — CHEMISTS — METALLURGISTS

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JANUARY 23, 1971

AMERICAN SMELTING AND REFINING COMPANY
POST OFFICE BOX 1111
EL PASO, TEXAS 79946

JOB No. E70-157

ATTENTION: MR. WILLIAM R. NASMYTH

RE: 500TPD CONVERTER GAS ACID PLANT
EL PASO PLANT
EL PASO, TEXAS

GENTLEMEN,

OUR SOIL AND FOUNDATION INVESTIGATION REPORT ON THE REFERENCED PROJECT IS HEREWITH SUBMITTED. THE INVESTIGATION WAS MADE IN CONJUNCTION WITH SERGENT, HAUSKINS & BECKWITH, CONSULTING SOIL AND FOUNDATION ENGINEERS. THE REPORT INCLUDES THE RESULTS OF TEST DRILLING, LABORATORY ANALYSIS AND RECOMMENDATIONS FOR FOUNDATION DESIGN.

SHOULD ANY QUESTIONS ARISE CONCERNING THE REPORT, WE WOULD BE PLEASED TO DISCUSS THEM WITH YOU.

RESPECTFULLY SUBMITTED,
DICKINSON LABORATORIES, INC.

BY _____
GEORGE G. DICKINSON

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500TPD Converter Gas Acid Plant
El Paso Plant
El Paso, Texas
Job No. E70-157

INTRODUCTION

This report is submitted pursuant to a soil and foundation investigation made by this firm of the site of the proposed 500TPD Converter Gas Acid Plant located at the American Smelting and Refining Company El Paso Plant, El Paso, Texas. The object of the investigation was to determine the physical characteristics of the subsoils underlying the site to provide recommendations for safe and economical foundation design.

PROPOSED CONSTRUCTION

Precise structural details of the project are not available. However, based upon preliminary information and the loads involved at the Sulfuric Acid Plant at the ASARCO Hayden Plant, it is anticipated that loadings will be approximately as follows:

1. The 6000 ton Acid Storage Tanks will be 58 feet in diameter and impose net bearing pressures of about 4500 psf.

2. Loads for the Cooling Tower, Product Acid Coolers, Absorption Tower, Converter, SO_2 Drying Tower and Liquid Cooling Tower are such that bearing pressures on mat-type foundations of their plan dimensions are in the range of 500 to 2000 psf. Most of these structures can withstand comparatively large differential foundation movements without interferring with their functions.

3. The Precipitators involve column loads on the order of 250 kips and are extremely sensitive to differential settlement.

INVESTIGATION

Twenty-three exploratory borings were drilled to depths varying between about 25 and 85 feet below existing grade. Logs of the test borings and site plans showing the boring locations are presented in Appendix A. Surveys to lay out borings and provide elevations were performed by the American Smelting and Refining Company.

Standard penetration testing and undisturbed sampling were performed at selected intervals in the borings. The test drilling was performed with CME-55 drill rig with borings first being advanced with 6½ inch hollow stem auger. When refusal occurred, drilling was continued with 3-1/8 inch tricone gear bits using water or a bentonite slurry as a drilling fluid. A brief description of drilling and sampling equipment and procedures also is included in Appendix A. The test drilling was directed by George H. Beckwith of this firm and William R. Wood, field geologist of Dickinson Laboratories, Inc.

Moisture content determinations were performed on all samples recovered. The results of these tests are shown on the boring logs.

Grain-size analysis and Atterberg Limits tests were run on selected samples to aid in soil classification. Due to the hard cemented nature of the native soils, undisturbed samples could not be recovered in most cases. However, direct shear and consolidation tests were performed on a representative sample of the firmer native soils. Test results are

PRESENTED IN APPENDIX B ALONG WITH A BRIEF DESCRIPTION OF SOIL MECHANICS TESTING PROCEDURES.

SITE CONDITIONS & SOIL PROFILE

THE SMELTER HAS BEEN IN OPERATION SINCE THE 1880'S AND ITS DEVELOPMENT HAS RESULTED IN HETEROGENEOUS FILLS OVER MUCH OF THE PLANT AREA. THE EXTREME VARIABILITY OF THESE FILLS HAS BEEN ILLUSTRATED BY 4 PREVIOUS SOILS INVESTIGATIONS MADE BY THIS FIRM AT ADJACENT AREAS OF THE PLANT. THE SOILS ENCOUNTERED IN THIS INVESTIGATION CAN BE DESCRIBED AS FOLLOWS.

1. SLAG FILL. SMELTER SLAG WAS ENCOUNTERED IN MOST BORINGS AND EXTENDED TO DEPTHS AS GREAT AS 47½ FEET. THE SLAG WAS INITIALLY DEPOSITED IN MOLTEN FORM AND HAS FUSED IN PLACE. THE UNDISTURBED SLAG HAS THE PROPERTIES OF SOFTER ROCK AND IS AN EXCELLENT MATERIAL FOR FOUNDATION SUPPORT. HOWEVER, IN MANY AREAS, THE SLAG HAS BEEN EXCAVATED AND REDEPOSITED AND IS INTERMIXED WITH LAYERS OF LOOSE FINER GRAINED SOILS, CONCRETE AND METAL FRAGMENTS, BRICK AND OTHER DEBRIS.

   THE FRACTURING ASSOCIATED WITH COOLING OF THE SLAG HAS RESULTED IN PARTICLES PREDOMINANTLY OF COARSE GRAVEL SIZE. ISOLATED PARTICLES OF FUSED SLAG 5 FEET OR MORE IN DIAMETER ARE PRESENT.

2. SOIL FILL. LAYERS OF FILL COMPRISED PREDOMINANTLY OF SILTY SAND AND GRAVEL AND CONTAINING VARYING AMOUNTS OF DEBRIS ARE PRESENT IN SOME AREAS OF THE SITE. THESE FILL MATERIALS OVERLIE THE NATIVE SOILS AND SLAG FILL IN SOME CASES AND IN OTHER CASES ARE INTERMIXED WITH THE SLAG FILL. IN GENERAL, THESE FILL MATERIALS ARE LOOSE AND COMPRESSIBLE.

3. TERRACE DEPOSITS. IN MANY AREAS, THE UPPER PORTION OF THE NATIVE SOILS CONSIST OF CLEAN, UNCEMENTED SANDS AND GRAVELS WHICH ARE RECENT TERRACE DEPOSITS OF THE RIO GRANDE RIVER. GENERALLY, THESE SOILS ARE MEDIUM IN RELATIVE DENSITY.

4. CEMENTED ALLUVIAL DEPOSITS. THE FILL MATERIALS AND/OR TERRACE DEPOSITS ARE UNDERLAIN IN ALL CASES BY CEMENTED ALLUVIAL DEPOSITS CONSISTING OF CLAYEY SANDS AND SANDY CLAYS INTERBEDDED WITH LESSER AMOUNTS OF SILTY SANDS AND HIGHLY PLASTIC CLAYS. THESE SOILS WHICH CONTAIN VARYING AMOUNTS OF GRAVEL AND COBBLES ARE FIRM TO HARD AND ARE EXCELLENT MATERIALS FOR FOUNDATION SUPPORT.

SOLID ROCK WAS ENCOUNTERED AT 72½ FEET IN BORING 17.

FREE GROUND WATER WAS ENCOUNTERED AT 17½ FEET IN BORING 2 IN THE AREA OF AN OLD CHLORINE WATER SETTLING BASIN. THIS GROUND WATER IS APPARENTLY PERCHED IN THE SLAG FILL ON TOP OF CEMENTED ALLUVIAL DEPOSITS. NO FREE GROUND WATER WAS ENCOUNTERED IN THE REMAINING BORINGS.

IT IS EMPHASIZED THAT THE SITE IS EXTREMELY VARIABLE AND CONSIDERABLE VARIATION IN SOIL CONDITIONS COULD OCCUR BETWEEN BORINGS.

DISCUSSION & RECOMMENDATIONS

ALTERNATIVES OF FOUNDATION DESIGN

GENERALLY, THE SLAG FILL IS FIRM AND WOULD PROVIDE ADEQUATE FOUNDATION SUPPORT FOR THE PROPOSED CONSTRUCTION. HOWEVER,

THE ISOLATED LOOSER ZONES OF SLAG FILL AND THE SOIL FILL ARE SUSCEPTIBLE TO LARGE SETTLEMENTS UNDER THE LOADS ANTICIPATED, PARTICULARLY IF THEY SHOULD BECOME SATURATED DUE TO SURFACE WATER INFILTRATION, RUPTURED CONDUITS, ETC.

IN VIEW OF THE FILL CONDITIONS DESCRIBED ABOVE FOUR ALTERNATIVES OF FOUNDATION DESIGN ARE RECOMMENDED FOR CONSIDERATION, DEPENDING ON THE SENSITIVITY OF THE STRUCTURES TO DIFFERENTIAL SETTLEMENT AND THE RELATIVE COSTS OF INITIAL FOUNDATION TREATMENT VERSUS RELEVELING THE STRUCTURES IN THE FUTURE SHOULD EXCESSIVE SETTLEMENTS OCCUR. THE ALTERNATIVES ARE AS FOLLOWS:

1. REMOVE AND RECOMPACT ANY LOOSE FILL LAYERS PRESENT AT THE SURFACE. DESIGN THE STRUCTURES TO WITHSTAND A DEGREE OF DIFFERENTIAL SETTLEMENT WITH THE USE OF A RIGID WAFFLE SLAB OR MAT-TYPE FOUNDATION AND PROVISION OF FLEXIBLE CONDUIT CONNECTIONS. THE STRUCTURES COULD THEN BE RELEVELED BY GROUTING SHOULD SETTLEMENTS BECOME EXCESSIVE.

2. REMOVE AND RECOMPACT ANY LOOSE FILL LAYERS PRESENT AT THE SURFACE. SUPPORT THE STRUCTURES ON SHALLOW SPREAD-TYPE FOOTINGS DESIGNED AT LOW BEARING PRESSURES WITH PROVISION FOR RELEVELING BY WEDGES, JACKING, ETC.

3. SUPPORT THE STRUCTURES ON FOUNDATIONS EXTENDED TO THE FIRMER NATIVE SOILS.

4. REMOVE AND PROPERLY RECOMPACT THE FILL DISCARDING COARSE PARTICLES, DEBRIS AND CLAY AND SUPPORT THE STRUCTURE ON SHALLOW FOUNDATIONS BEARING ON THE ENGINEERED FILL.

ALTERNATIVES 1 AND 2 WOULD, OF COURSE, INVOLVE A CALCULATED RISK OF EXCESSIVE SETTLEMENTS AND FUTURE COSTS OF RELEVELING.

The risk of such costs in most cases is believed to be remote. Alternatives 3 and 4 are positive treatments which would not be susceptible to excessive settlements.

Fill material was encountered to depths varying between 1½ and 8 feet in the Fuel Storage Tank area. Thus the fill can be efficiently overexcavated in this area with alternate 4 being used as a foundation system.

Fill depths are 14 and 17 feet in borings 1 and 4 in the Precipitator area. It would be practical to use alternate 3 or 4 in this area should settlement considerations be critical.

Fill depths in the areas of the Liquid Cooling Tower, Absorption Tower, Product Acid Coolers, Converter and Cooling Tower varied between 8 and 47½ feet and was over 20 feet in the majority of the borings. Because of the large fill depths and nature of these structures, it appears that alternates 1 or 2 will be the most economical approach.

Only 4 and 5 feet of fill is present at the New Spray Chamber and adjacent flues in the vicinity of borings 19, 19A and 20. Thus, spread-type footings can be economically advanced to native soils in that area (alternate 3). Because slag fill extended to 13½ and 15 feet at borings 21 and 22, alternate 2 probably will be the most economical approach for the support of the flues at these locations.

Detailed recommendations for the alternates given above are presented in the following sections of this report. The

RECOMMENDED BEARING VALUES APPLY TO FULL DEAD PLUS LIVE LOADS AND CAN BE SAFELY INCREASED BY ONE-THIRD FOR WIND OR SEISMIC FORCES.

Alternate 1 - Mat-Type Foundation Designed to Resist Settlement

PRIOR TO CONSTRUCTION OF MAT-TYPE OR WAFFLE SLAB FOUNDATIONS THE FILL SURFACE SHOULD BE COMPACTED BY 5 PASSES OF A HEAVY STEEL DRUM VIBRATING ROLLER (5 TON MINIMUM). RECENT RESEARCH HAS INDICATED THAT SIGNIFICANT COMPACTION CAN BE OBTAINED BY THIS MEANS TO DEPTHS UP TO ABOUT 6 FEET WHERE CLEAN GRANULAR SOILS ARE INVOLVED. THUS, THIS TREATMENT WILL TEND TO REDUCE THE POTENTIAL DIFFERENTIAL SETTLEMENT AND DETECT ANY LOOSE ZONES AT THE SURFACE. FOOTING EXCAVATIONS SHOULD BE INSPECTED BY A REPRESENTATIVE OF THE SOILS ENGINEER FOR LOOSE ZONES, DEBRIS, ETC. ANY LOOSE ZONES ENCOUNTERED SHOULD BE REMOVED AND REPLACED WITH COMPACTED FILL IN ACCORDANCE WITH THE REQUIREMENTS SET FORTH UNDER ALTERNATE 4 BELOW.

MAT FOUNDATIONS SHOULD BE RELATIVELY RIGID TO RESIST A DEGREE OF DIFFERENTIAL MOVEMENT. WHERE BEARING PRESSURES EXCEED 2,000 PSF, THIS FIRM SHOULD BE NOTIFIED FOR REVIEW OF TOTAL LOADS AND SOILS CONDITIONS AT THE SPECIFIC AREA.

POSITIVE SURFACE DRAINAGE SHOULD BE PROVIDED TO MINIMIZE INFILTRATION OF MOISTURE INTO ANY LOOSE ZONES OF FILL THAT MIGHT UNDERLIE FOUNDATIONS.

Alternate 2 - Spread-Type Footings Designed for Releveling

COMPACTION OF THE FILL SURFACE AND INSPECTION AND REMOVAL OF

ANY LOOSE ZONES DETECTED SHOULD BE PERFORMED AS RECOMMENDED ABOVE FOR ALTERNATE 1.

A MAXIMUM SAFE SOIL BEARING PRESSURE OF 2,000 PSF IS RECOMMENDED. MINIMUM DEPTH OF FOOTING SHOULD BE $1\frac{1}{2}$ FEET BELOW THE LOWEST ADJACENT FINISHED GRADE. IT IS ESTIMATED THAT SETTLEMENTS OF FOOTINGS SO DESIGNED WILL NOT EXCEED $\frac{3}{4}$ INCH UNLESS LOOSE ZONES BENEATH FOOTINGS BECOME SATURATED.

FREE SURFACE DRAINAGE SHOULD BE PROVIDED TO PREVENT INFILTRATION OF MOISTURE INTO THE FILL BENEATH THE FOOTINGS.

ALTERNATE 3 - FOUNDATIONS ON NATIVE SOILS

DUE TO THE DEPTH OF FILL, THE USE OF DRILLED PILING WILL BE THE MOST EFFICIENT MEANS OF ADVANCING FOUNDATIONS TO NATIVE SOILS IN MOST CASES. DRILLED CAST-IN-PLACE CONCRETE PILES EXTENDED TO THE CEMENTED NATIVE SOILS SHOULD BE DESIGNED ON AN END-BEARING BASIS USING A SAFE SOIL BEARING PRESSURE OF 12,000 PSF. THEY SHOULD PENETRATE THE BEARING STRATUM A MINIMUM OF 6 INCHES. FROM PREVIOUS EXPERIENCE AT THE FACILITY, IT APPEARS THAT BELLING (ENLARGEMENT OF BASES) CAN BE PERFORMED IN THE MATERIALS INVOLVED WHERE THE RATIO OF BELL TO SHAFT DIAMETER DOES NOT EXCEED 2.

HAND BELLING PROBABLY WOULD BE NECESSARY IN MOST CASES.

THE CAVING TENDENCIES OF THE LOOSER FILL AND TERRACE DEPOSITS AND THE PRESENCE OF COBBLE SIZE PARTICLES WILL COMPLICATE FOUNDATION DRILLING. TEST DRILLING AT THE ASARCO HAYDEN PLANT IN SIMILAR SLAG INDICATED THAT FOUNDATIONS CAN BE ADVANCED THROUGH THE SLAG WITH TEXOMA 35 OR HUGHES LDH-30 TYPE DRILL RIGS ALTHOUGH DRILLING CONDITIONS WERE EXTREMELY DIFFICULT. CONSIDERABLE HAND

labor would be necessary in advancing excavations through slag, particularly where large fused fragments and debris are present.

It appears that excavations can be drilled to the contact of the native soils without the use of casing. However, temporary casing will be necessary for the protection of workmen and inspectors. All foundation excavations should be entered and inspected by a representative of the soils engineer to insure that proper contact with the cemented alluvial deposits is obtained and that all loose disturbed material is removed from the entire end-bearing areas. Manual cleaning will be necessary in the materials involved. Minimum shaft diameter should be 2 feet as piles with smaller shafts are difficult to properly clean and inspect.

Any annular space around the casing should be filled with clean sand prior to placement and vibration of concrete and withdrawal of casing so that an over-run of concrete quantity is prevented.

Spread-type footings bearing on the shallow terrace deposits in the vicinity of borings 19, 19A and 20 should be designed using a safe soil bearing pressure of 5,000 psf.

Maximum settlements of foundations designed by the above criteria are estimated at $\frac{3}{4}$ inch. Settlements will occur rapidly and be essentially complete at the end of construction.

Alternate 4 - Foundations on Engineered Fill

With the treatment outlined below, a safe soil bearing pressure

of 5,000 psf is recommended for the design of spread-type footings bearing on engineered fill. A bearing pressure of 8,000 psf should not be exceeded at the base of the Acid Storage Tanks where engineered fill is provided. Minimum depth of footing should be 1.5 feet below the lowest adjacent finished grade. Minimum recommended footing widths are 2.0 feet and 1.33 feet for square and continuous footings, respectively.

Maximum settlements of foundations designed as recommended above are estimated at $\frac{3}{4}$ inch. The rate will be rapid with settlements being essentially complete during construction.

All fill should be removed from the area of the structures and for a distance outside of their perimeters equal to the depth of engineered fill. Engineered fill should then be placed in horizontal lifts up to subgrade elevation.

The engineered fill should be free of vegetation, debris and other deleterious material, contain no particles larger than 6 inches in diameter and have no more than 25 percent by weight passing the no. 200 sieve. The plasticity index should be no greater than 15. Most of the existing fill including slag will meet these requirements with the removal of isolated coarse particles, debris and clayey zones.

The portion of the fill that can be tested by conventional density determinations (generally that portion with 50 percent or more passing the no. 4 sieve) should be compacted to a minimum of 95 percent of maximum density as determined by ASTM D1557-66T. For purposes of acceptance, the in-place

DENSITY OF THE FILL SHOULD BE DEFINED AS THAT DETERMINED BY THE SAND CONE METHOD (ASTM D1556-64) OR THE RUBBER BALLOON METHOD (ASTM D2167-66).

DUE TO THE COARSE GRADATION OF THE SLAG, IT WILL NOT BE PRACTICAL TO PERFORM COMPACTION CONTROL BY MEANS OF CONVENTIONAL FIELD DENSITY TESTS. ACCORDINGLY, IT IS RECOMMENDED THAT COMPACTION OF THE SLAG AND OTHER COARSE GRANULAR MATERIALS USED AS ENGINEERED FILL BE CONTROLLED ON A "MINIMUM ROLLING" BASIS AS FOLLOWS.

1. LIFTS SHOULD BE PLACED SO THEIR THICKNESS, WHEN COMPACTED, DOES NOT EXCEED 12 INCHES.

2. COMPACTION SHOULD BE ACCOMPLISHED BY A SPECIFIED NUMBER OF PASSES OF EQUIPMENT APPROVED BY THE SOILS ENGINEER. THE FOLLOWING TYPES OF PNEUMATIC ROLLERS ALSO WILL BE SATISFACTORY.

ROLLER TYPE	ROLLER RATING	WHEEL LOAD	TIRE INFLATION PRESSURE
A	45 TON MIN.	11 TON MIN.	140 PSI MIN.
B	45 TON MIN.	5½ TON MIN.	90 PSI MIN.

THREE PASSES OF ROLLER A OR SIX PASSES WITH ROLLER B WOULD BE SATISFACTORY COMPACTIVE EFFORT. OTHER TYPES OF ROLLERS CAN BE EVALUATED AS TO SUITABILITY AND REQUIRED COMPACTIVE EFFORT ESTABLISHED FOR THOSE WHICH ARE ACCEPTABLE. FOR SLAG OR OTHER COHESIONLESS GRANULAR PORTIONS OF THE FILL, FIVE PASSES WITH EITHER A HEAVY CRAWLER-TYPE FRACTOR (20 TON MIN.) OR A HEAVY STEEL-DRUM VIBRATING ROLLER (5 TON MIN.) WILL BE SUFFICIENT COMPACTIVE EFFORT.