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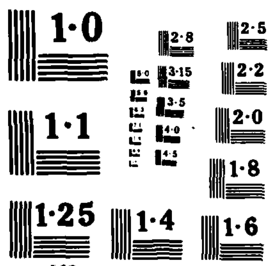
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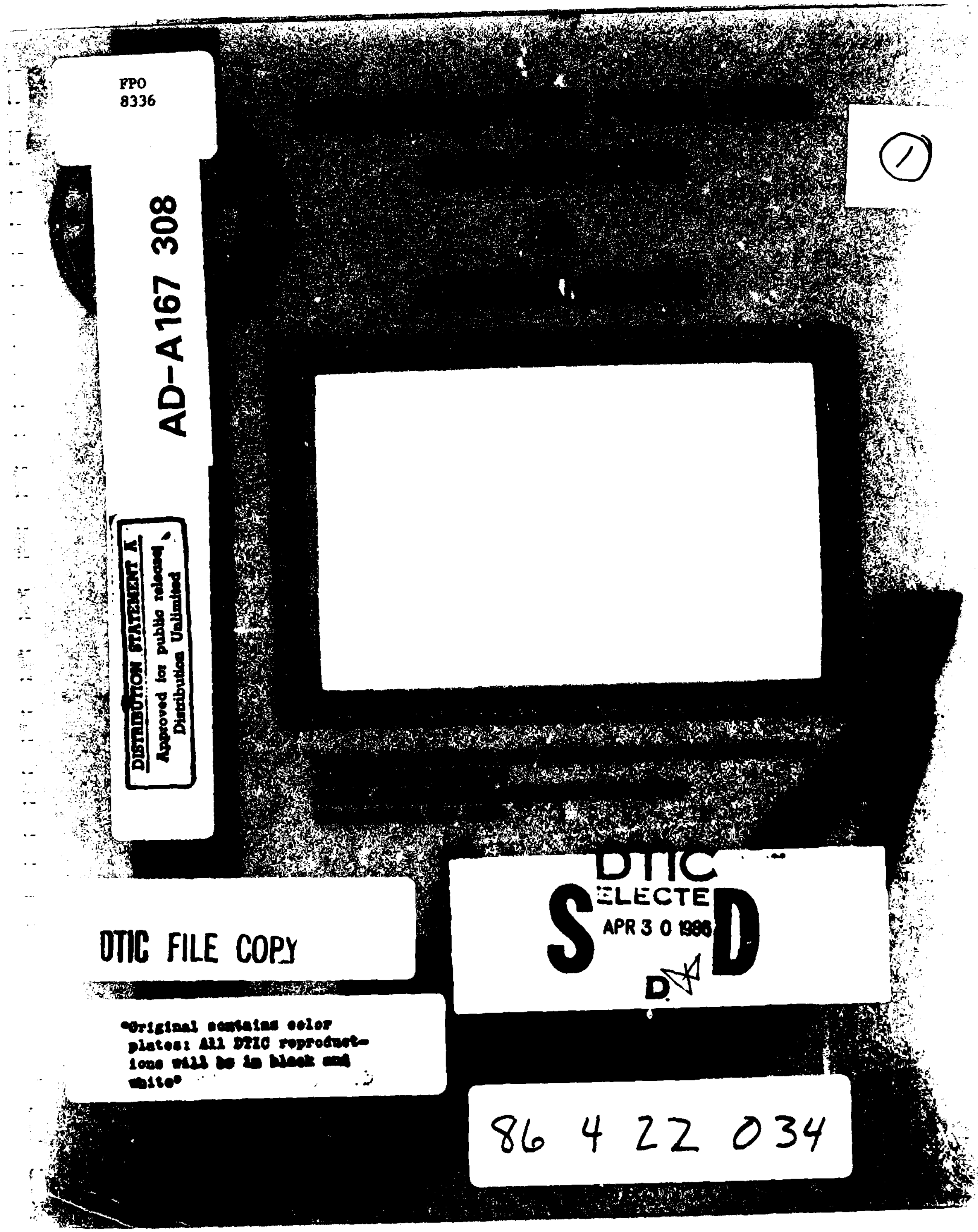

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UNDERWATER FACILITIES INSPECTIONS AND ASSESSMENTS AT

TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA

FPO-1-83-(36) SEPTEMBER 1983

PERFORMED FOR: OCEAN ENGINEERING AND CONSTRUCTION PROJECT OFFICE
CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, D.C. 20374

UNDER: CONTRACT N62477-81-C-0448
TASK 8

BY: CHILDS ENGINEERING CORPORATION
MEDFIELD, MA

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19. ABSTRACT (Continue on reverse if necessary & identify by block number)
The objective of the Underwater Facility Assessments conducted at the Trident Refit Facility, Naval Submarine Base, Bangor, Washington is to provide a generalized structural condition report of various elements of the Drydock. The inspection was performed by a team of engineer/divers using visual/ (Con't)

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tactile and non-destructive technique. Typical and unusual conditions were photo-documented.

The elements of the Drydock which were inspected include 1878 exposed steel sheet piles, the concrete abutment and the caisson.

The drydock was accepted by the Navy in December of 1980.

The condition of the exposed steel sheet piling is excellent as is the condition of the concrete abutment and the caisson.

No repairs are necessary at this time. The Drydock should be re-inspected in three (3) years. The estimated cost to re-inspect the Drydock is $40,000.00.

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This report was performed under the Underwater Inspection Program conducted by the Ocean Engineering and Construction Project Office (FPO-1), Chesapeake Division, Naval Facilities Engineering Command (NAVFACENGCOM) as a part of NAVFAC's Specialized Inspection Program.

This program sponsers task-oriented engineering services for the inspection, analysis and design, and monitoring of repairs for the submerged portions of selected Naval Waterfront Facilities. All services required to produce this report were provided by Childs Engineering Corporation of Medfield, Massachusetts under Task No. 8.0 of Contract No. N62477-81-C-0448.

1.1 REPORT CONTENT

The report contains a description of inspection procedures, the results of the inspection and analysis of the findings, accompanied by pertinent drawings and photographs. Specifically, the inspection results include a description of the location, the facility, its observed condition and a structural assessment of that condition. Recommendations for repair of the facility and cost estimates (based on present local prices) for any repair work are also included, where necessary. Estimated cost breakdowns to reinspect the drydock can be found in the Appendix.

EXECUTIVE SUMMARY

The objective of the Underwater Facility Assessments conducted at the Trident Refit Facility, Naval Submarine Base, Bangor, Washington is to provide a generalized structural condition report of various elements of the Drydock. The inspection was performed by a team of engineer/divers using visual/tactile and non-destructive techniques. Typical and unusual conditions were photo-documented.

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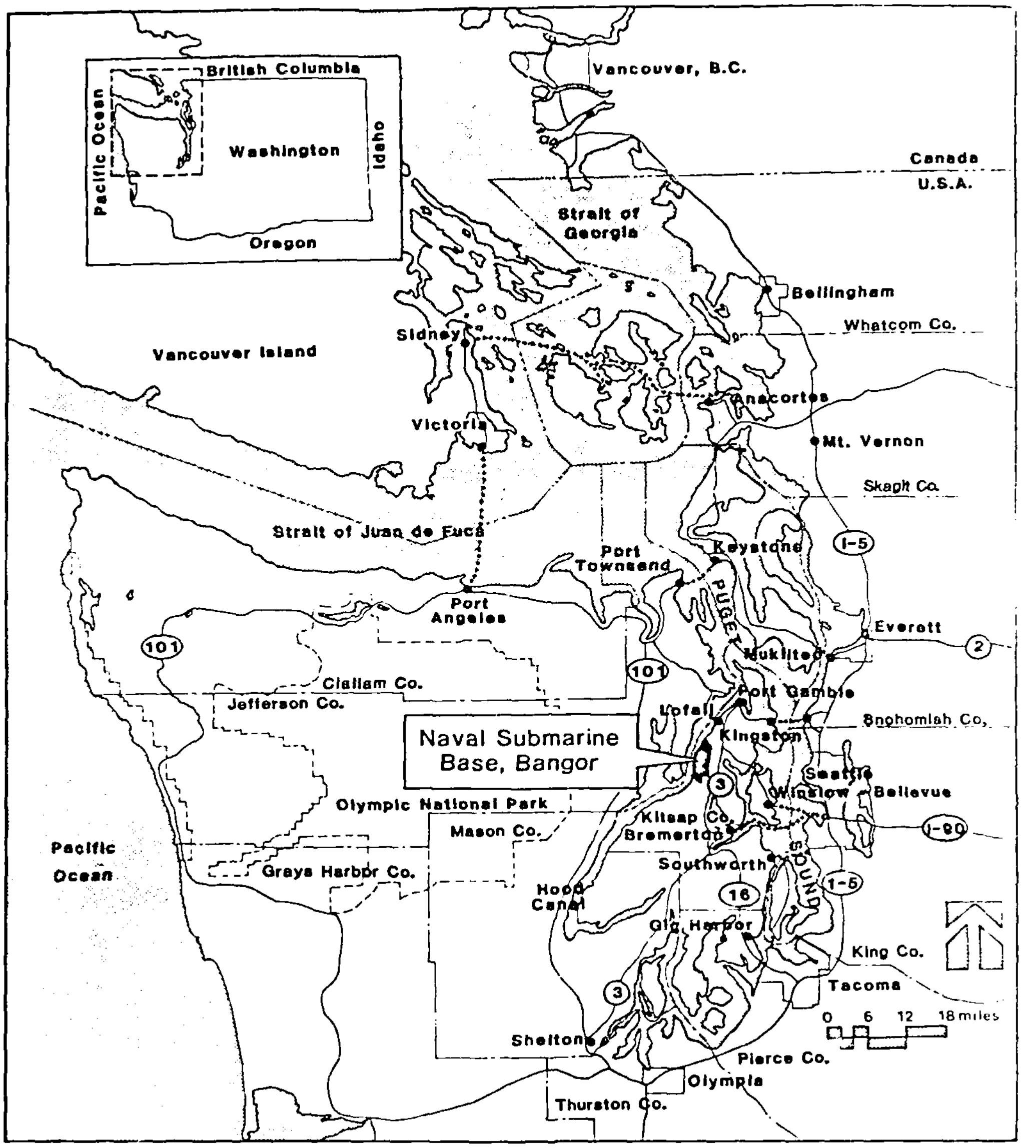
The condition of the exposed steel sheet piling is excellent as is the condition of the concrete abutment and the caisson.

No repairs are necessary at this time. The Drydock should be re-inspected in three (3) years. The estimated cost to re-inspect the Drydock is $40,000.00.

The purpose of this section is to provide a general description of the Trident Refit Facility, Naval Submarine Base, Bangor, Washington. The section includes a brief description of the Trident Support Site's location and existing facilities. The information is provided to aid in identification of the facility and to support all considerations necessary to accurately assess the condition of the facility inspected under this task.

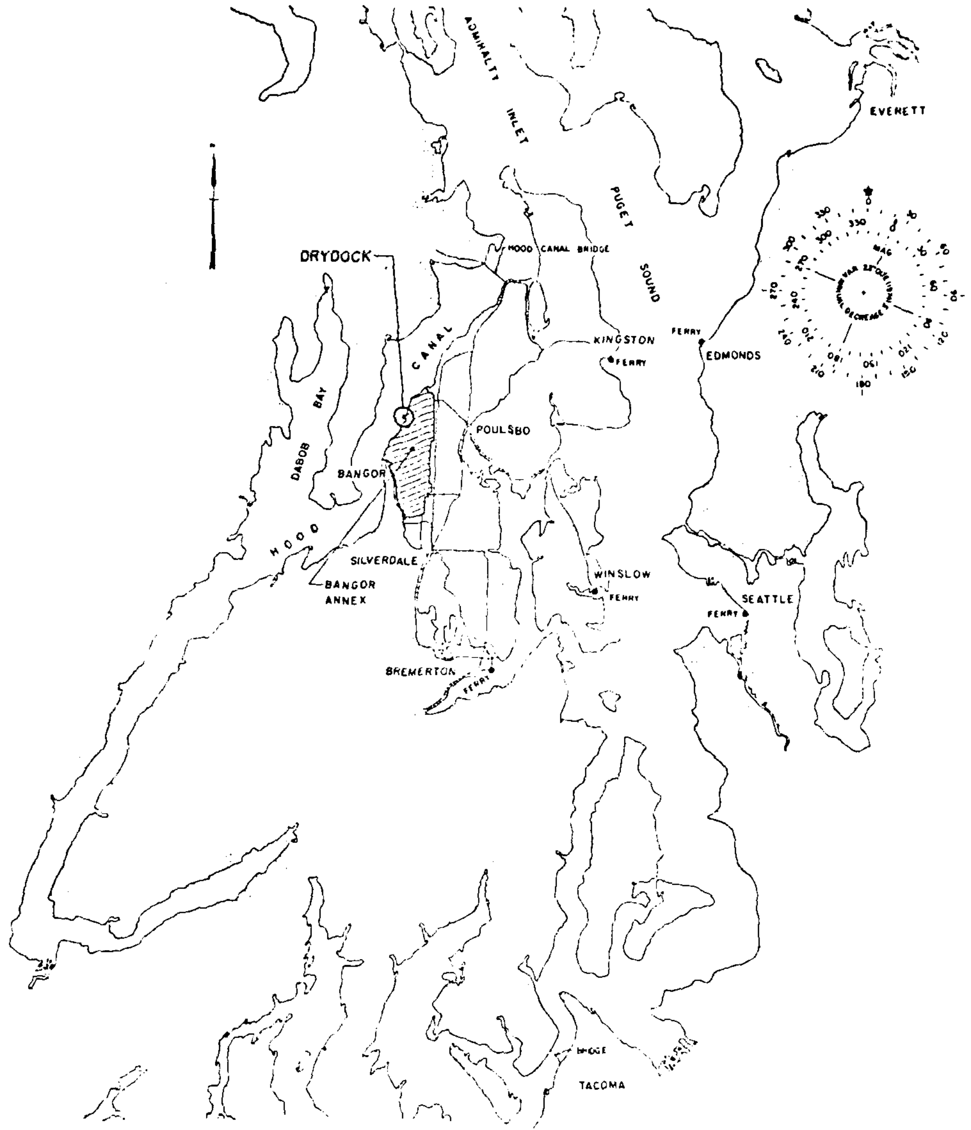
2.1 LOCATION OF ACTIVITY

The Trident Support Site is located at the Naval Submarine Base, Bangor, on Kitsap Peninsula in Puget Sound, due west of Seattle, Washington (see Figure 1). The site area is that generally included within the activity area of existing Bangor Annex, NTS, Keyport (see Figure 2). The site is rural in nature, and the nearest urban areas are Silverdale, Poulsbo and Keyport, with approximate populations of 1,000, 1,700 and 500, respectively. The Greater Seattle Metropolitan Area with a population of approximately 500,000 is about a one-half hour drive by road plus about a one-half hour ferry ride aboard the Seattle-Winslow ferry. Tacoma, another major population area of approximately 175,000, is approximately 45 miles south using the Narrows Bridge. Bremerton, having a population of approximately 40,000, is the location of the existing Naval shipyard and is 13 miles to the south of the Bangor Annex. (Reference 1)



REFERENCE FROM: MASTER PLAN - NAVAL SUBMARINE BASE, BANGOR, WA

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD, MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D.C.	
AS SHOWN		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA LOCATION MAP	FIG. 1



REGIONAL MAP

0 1 2 3 4 5 10
SCALE IN MILES

FROM NOAA CHART NO 18446 AND NO 18441

REFERENCE FROM: NAVFAC DWG NO. 6042350.

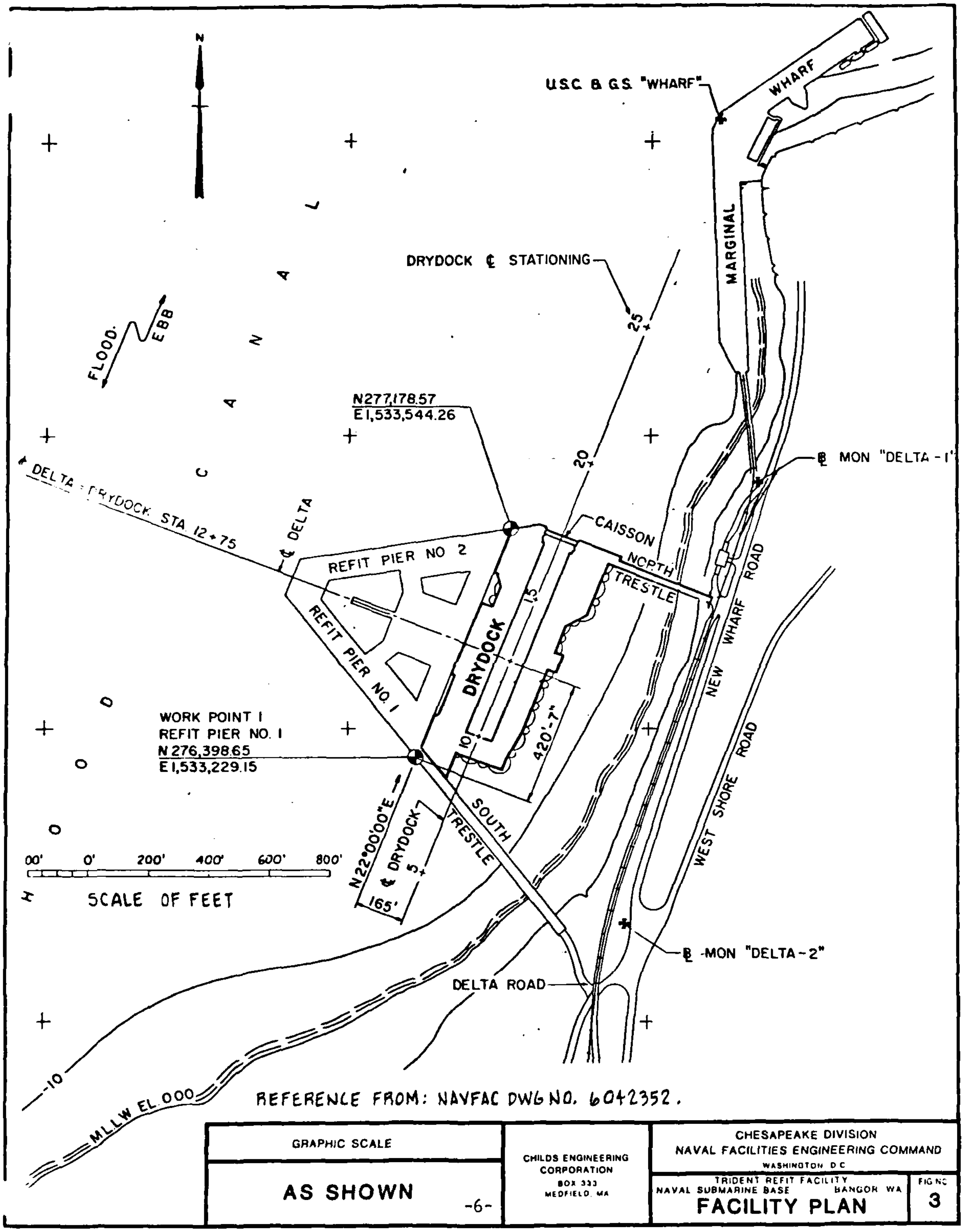
GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D C
AS SHOWN		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA **VICINITY MAP** — FIG. 2

The Bangor Annex, NTS, Keyport was established in 1944 as a Pacific Coast transshipment point for ammunition and explosives. Prior to 1970, the Annex was known as the Naval Ammunition Depot (NAD), Bangor and encompassed over 8,000 acres of land. The existing administrative, industrial and production facilities, POMFPAC and a number of Keyport facilities occupy 6,929 acres. Right-of-way for a Navy-owned railroad from Bangor to Shelton constitutes an additional 830 acres. The balance of the 8,572 acres is comprised of 768 acres directly across Hood Canal on the Toandos Peninsula. (Reference 1)

2.2 EXISTING FACILITIES

The primary waterfront structures at the Trident Refit Facility are two (2) refit piers and a drydock. The three (3) elements are linked in a triangular shape which is referred to as the Delta Support Facility (see Figure 3 and Photo #1).

Reference 1 - Trident Support Site Master Plan


N
U.S.C. & G.S. "WHARF"
WHARF
MARGINAL
DRYDOCK ℄ STATIONING
25
20
15
10
5
FLOOD
EBB
H O O D C A N A L
N277,178.57
E1,533,544.26
℄ MON "DELTA-1"
℄ DELTA-DRYDOCK STA. 12+75
℄ DELTA
REFIT PIER NO. 2
CAISSON
NORTH TRESTLE
NEW WHARF ROAD
REFIT PIER NO. 1
DRYDOCK
420'-7"
WORK POINT 1
REFIT PIER NO. 1
N 276,398.65
E 1,533,229.15
N22°00'00"E
℄ DRYDOCK
165'
SOUTH TRESTLE
WEST SHORE ROAD
00' 0' 200' 400' 600' 800'
SCALE OF FEET
℄ -MON "DELTA-2"
DELTA ROAD
-10
MLLW EL. 000
REFERENCE FROM: NAVFAC DWG NO. 6042352.
GRAPHIC SCALE
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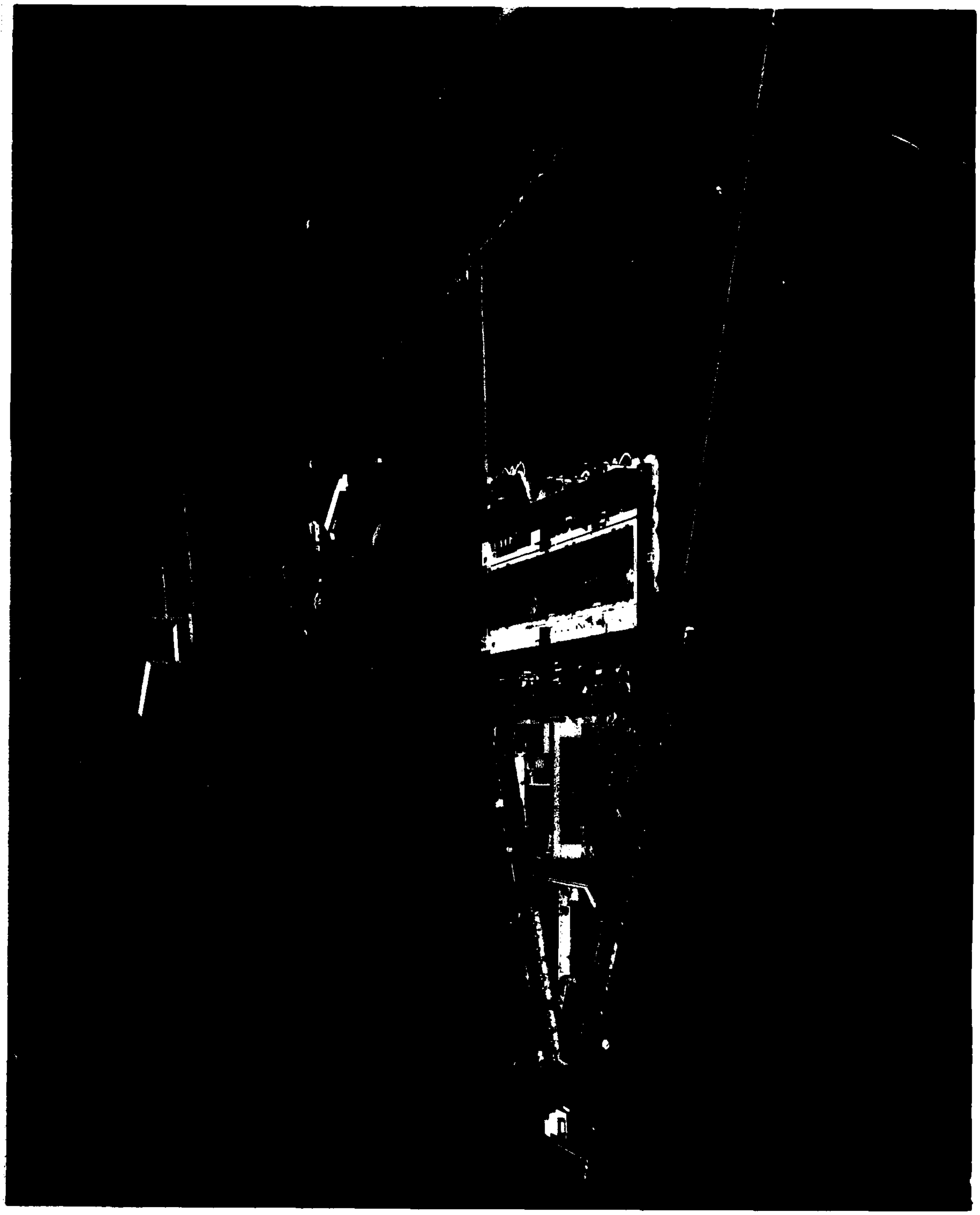
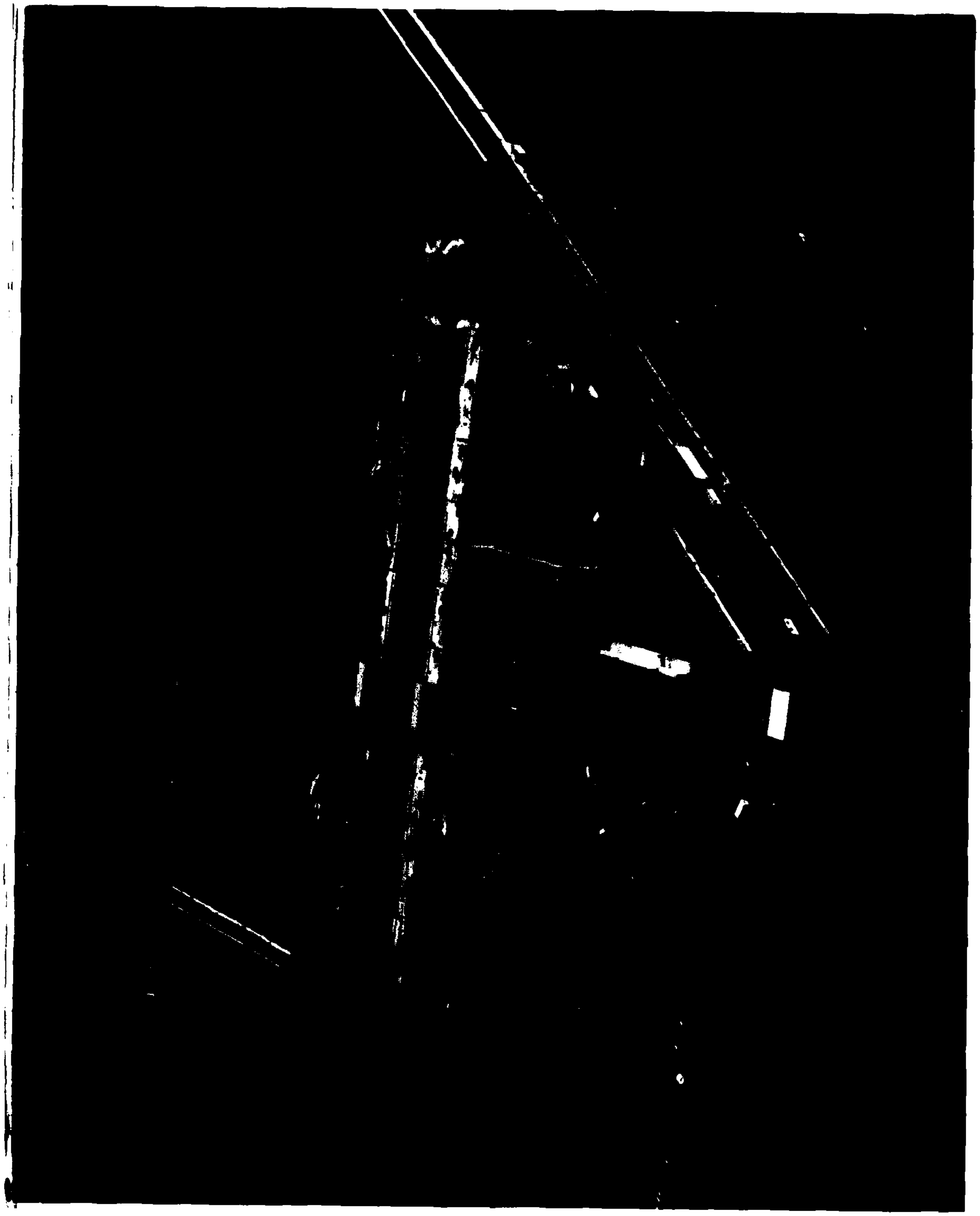
CHILDS ENGINEERING CORPORATION
BOX 333
MEDFIELD, MA
CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON D.C.
TRIDENT REFIT FACILITY
NAVAL SUBMARINE BASE BANGOR WA
FACILITY PLAN
FIG NO
3





Between July 11 and August 10 of 1983, a three-person engineer/diver inspection team performed an on-site underwater inspection of the exterior of the drydock at the Trident Refit Facility, Bangor, Washington. The level of inspection to be performed, the type of structure being inspected, actual on-site conditions and past experience, combined with a thorough knowledge of engineering theory, dictated the inspection procedures that were followed.

3.1 LEVEL OF INSPECTION

The inspection techniques used had to be sufficient to yield information necessary to make a general condition assessment of the drydock structure, identify any areas that were mechanically damaged or in advanced states of deterioration and formulate repair and maintenance recommendations with cost estimates. In general, this meant utilizing visual/tactile and non-destructive inspection techniques. Photographic documentation of typical as well as unusual conditions were also obtained.

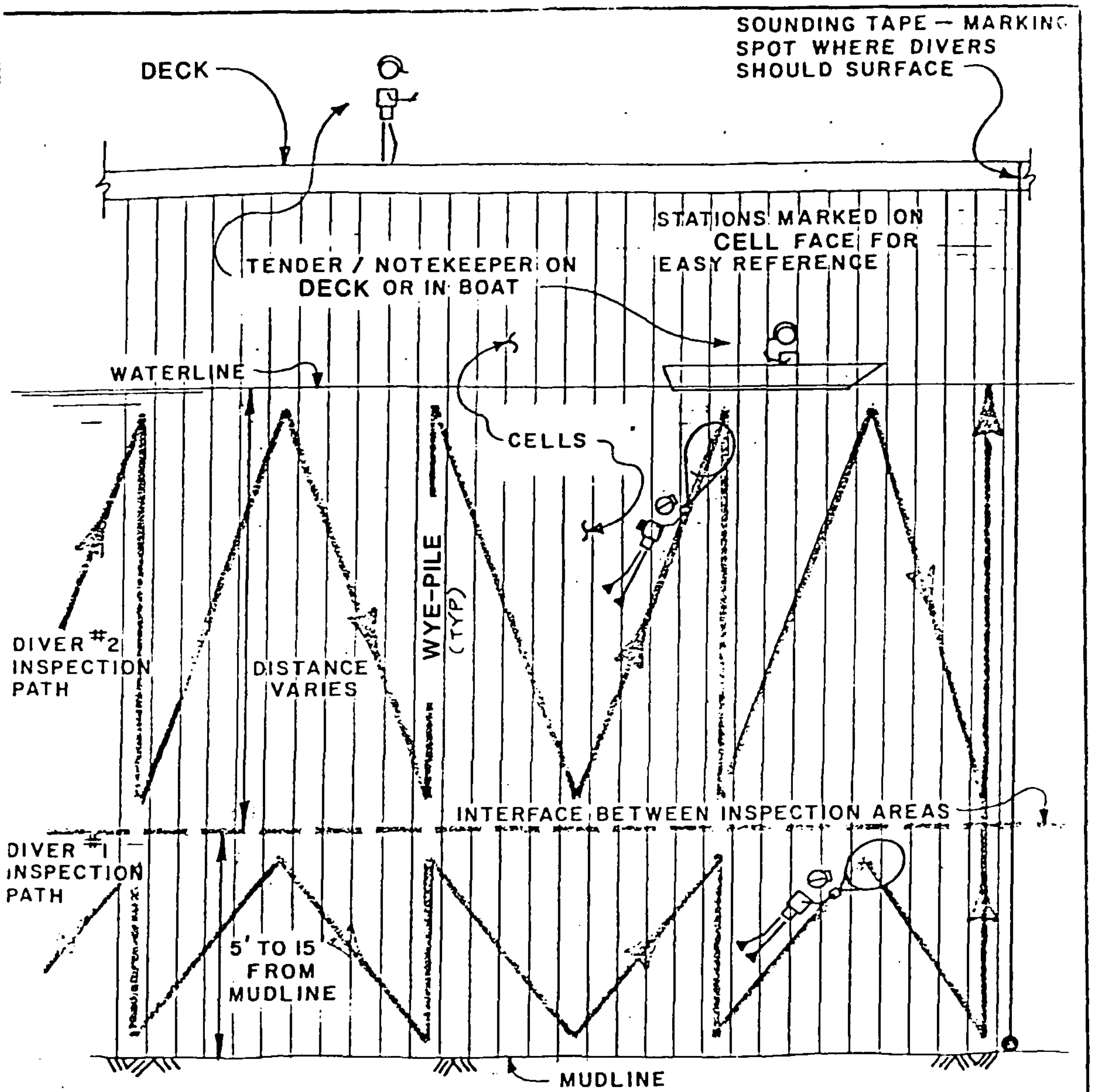
Particular emphasis was placed on obtaining metal thickness measurements of the steel sheet piles which comprise the cellular cofferdams around the drydock such that an accurate "baseline" is established for future inspections.

3.2 INSPECTION PROCEDURE

A dive team consisting of two divers and a tender performed the on-site inspection. A Level I general inspection was performed on all exposed steel sheet piling of the cells and arcs associated with the drydock. A Level I general inspection was also performed on the exposed face of the caisson gate, gate abutment, exposed seals, drydock intake and discharge structure. The Level I inspection was performed to determine the general condition of the structure and is primarily a visual/tactile type inspection. The typical inspection path for the Level I inspection of the cells and arcs is illustrated in Figure 4.

A Level II inspection, which is a close visual/tactile inspection usually requiring cleaning of marine growth, was performed on all wye piles which connect the arcs to the cells. The wye piles are closely inspected since they are extremely susceptible to severe stress as a result of the difficulty in installing cells and arcs in a theoretical configuration. Interlock failures are not uncommon at wye piles and close examination will reveal such a failure.

In addition, Level II inspections were performed on one sheet pile per cell/arc group for the full pile length and on two additional sheet piles per cell/arc group in the tidal zone.



NOTE:
ACTUAL PATH(WIDTH AND HEIGHT) FOR DIVERS VARIES WITH CLARITY OF WATER, AGE OF FACILITY, OBSTRUCTIONS, ETC. ASSURING ALL PORTIONS OF THE CELLS ARE EXAMINED.

TYPICAL DIVER INSPECTION PATH FOR SHEET PILE CELLS

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD, MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D.C.	
N/A		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA **DRYDOCK**	FIG NO 4

A Level III inspection which includes measurement of steel thickness was performed on all piles which received a Level II inspection. An ultrasonic measurement device was used to obtain the metal thickness. Because this inspection is intended to provide a "baseline" for all future inspections over five hundred thickness measurements were taken and the location of each reading documented.

In addition to the steel thickness measurements, electrical potential measurements were taken on selected piles which received a Level III inspection. The measurements were taken to assist in assessing the effectiveness of the cathodic protection system.

It should be noted that non-destructive methods of inspection were employed. The conditions noted reflect direct observation of structural components. Information which may infer knowledge of conditions not accessible by non-destructive testing methods is based on government-furnished documents, our knowledge of structures in similar environments and/or generally accepted engineering theories.

3.3 INSPECTION EQUIPMENT

Equipment used for the inspection included a Minolta SRT200 camera with 28mm and 200mm lenses and strobe, a Nikonos IVA underwater camera with strobe, a Krautkramer-Branson, Inc. type DM-1B ultrasonic thickness meter, a Roxby Engineering

International, Ltd. Mark V Bathycorrometer voltmeter, dive lights, sounding tapes, survey tapes, 8-foot folding rules, chipping hammers and dive knives.

Choice of equipment was made as a result of past experience. Most of the equipment is straightforward, easy to implement, and has proven reliable under hard use.

SECTION 4.0 FACILITY INSPECTION

Within this section of the report the results of the inspection of selected elements of the drydock, Trident Refit Facility at the Naval Submarine Base, Bangor, Washington is presented. To provide a clear understanding of the work accomplished and the results of the inspection, this discussion is presented in four parts:

1) a description of the construction and function of the structure, which is derived both from the on-site inspection and from the referenced government-furnished reports and drawings; 2) an enumeration of general and specific conditions observed during the on-site inspection; 3) a qualitative assessment of the structural condition of the facility based on the inspection data; and 4) recommendations for actions to be taken to ensure long-term, cost-effective maintenance and utilization of the facility. Detailed breakdowns of cost estimates are included in the Appendix.

4.1 DRYDOCK - TRIDENT REFIT FACILITY

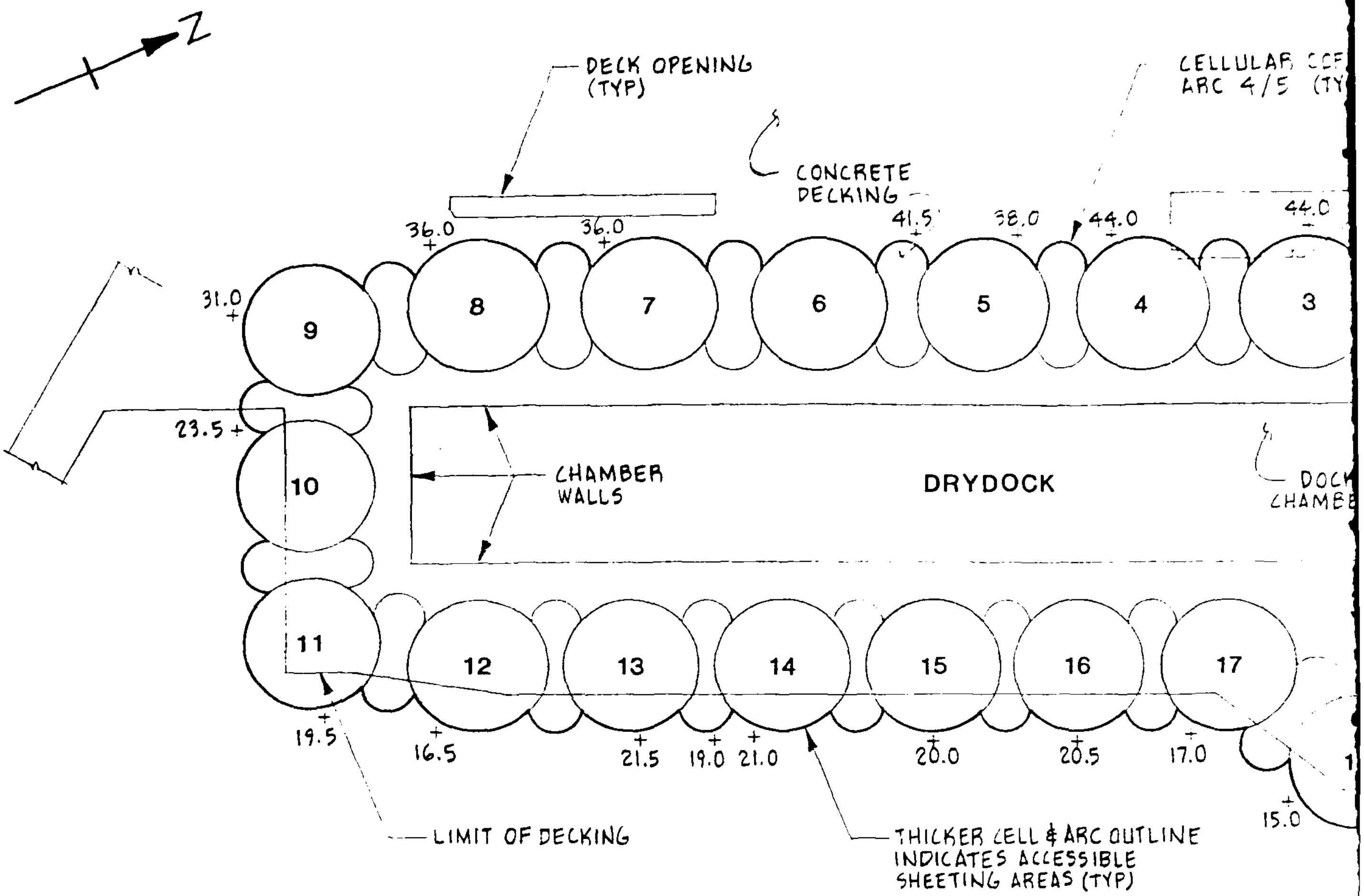
4.1.1 DESCRIPTION

The drydock is one element of the Delta Pier Complex which is comprised of the drydock and two refit piers. The Delta Pier is located on the eastern shore of the Hood Canal (see Figure 4). The drydock is used primarily to drydock Trident submarines for refit work.

The drydock was constructed between 1977 and 1979, and accepted by the Navy on December 27, 1980.

The principle inside dimensions of the drydock are 700'x90'x53' draft (M.H.H.W.) over the sill. The concrete floor, walls and caisson abutment which comprise the primary structure were constructed in the dry, within a cellular cofferdam basin. Twenty steel sheet pile cells and their connecting steel sheet pile arcs were left in place after the concrete work was complete (see Figure 5). According to the government-furnished information, the cells' and arcs' major structural function is to provide support for decking adjacent to the dock and lateral support for the crane rail piles.

The total number of exposed sheet piles is 1833, and there are 39 exposed wye piles connecting the cells with the arcs. There are also four construction wye piles and two 90-degree Tee piles exposed. The sheet piles are provided with cathodic protection by 83 anodes and additional corrosion protection is provided on the exposed face of the sheets by a coating of coal-tar epoxy.



PLAN

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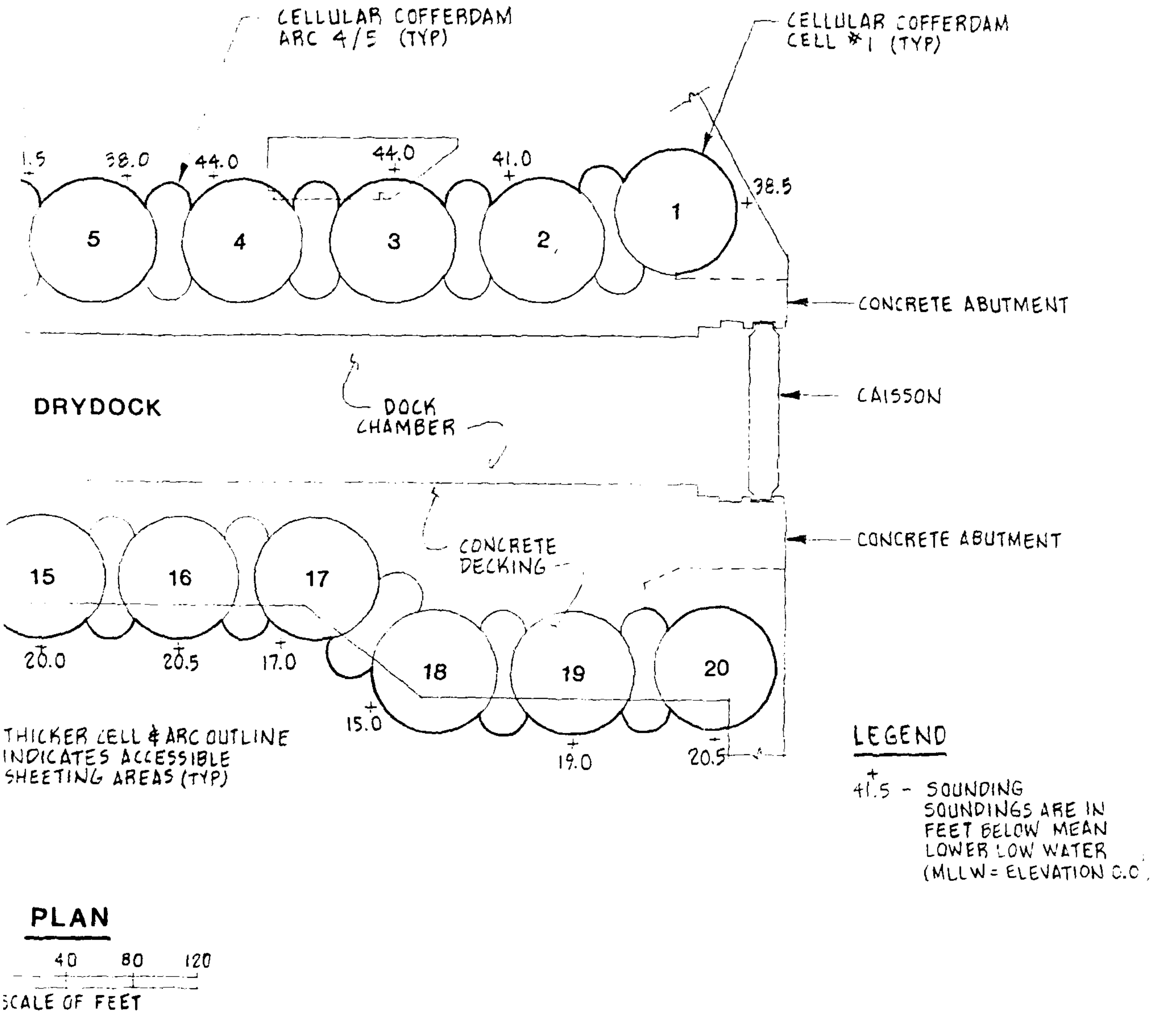
SCALE OF FEET

REFERENCE FROM: NAVFAC DWG NO. 6042317, 6042490 & 6042491.



GENERAL ARRANGEMENT

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD, MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON, D.C.	
AS SHOWN		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIG NO. 5

4.1.2 OBSERVED INSPECTION CONDITIONS

This section of the report presents the quantitative data obtained during the inspection and details the conditions observed during the inspection. In general, the quantitative data, such as steel thickness measurements, are presented in graphical or tabular format. This quantitative data is referenced in the description of observed conditions.

To provide the reader a clear understanding of the quantitative data presented, a discussion of ultrasonic thickness measurements is appropriate.

An excerpt from the "Operating Instructions, Type DM-1B, Krautkramer-Branson, Inc.", the instrument used to perform the thickness measurements, provides a simple yet concise explanation:

> "Ultrasonic wall thickness measurement resembles radar or sonar in its technique. A burst of ultra-sound is sent via a probe (transducer) into a material to be reflected at the material's backwall. After reflection, the ultra-sound is returned to the probe. The time interval between transmission and reception of the sound may be related to thickness if the speed at which the sound travelled in the material is known."

The particular instrument used provides a digital readout to five-thousandths of an inch (.005"). The last digit which is either 0 or

5 is generated from a calculation using velocity and time divided by 2. Simply put, an odd number answer to the calculation produces a reading of 5 and an even number answer produces a reading of 0.

The data presented in this report is unedited field data. All readings are to the theoretical 5/1000's of an inch. Our experience suggests that when making structural assessments, the field data be reduced by 5/1000's, i.e., a reading of .390" should be reduced to .385" for calculation purposes.

Inaccuracies in the thickness measurements may result if the surface of the steel is irregular or pitted. In general, if this condition is observed by the engineer, it will be noted or the reading will be rejected altogether and an alternate location is selected, if possible, on the steel.

In addition to the operation of the ultrasonic thickness gauge, it is important that the reader keep in mind rolling tolerances of steel shapes, plates and sheet piling. Since both weight and dimensional tolerances exist in the production of steel, these must be accounted for when reviewing the data. An example of this is as follows:

> Theoretical web thickness dimension of PSX32 sheet pile is 29/64" (.453). Rolling tolerance is 2.5% by weight. If weight is uniformly applied over the cross-section, this means that the web thickness may vary from .464" to .442". In fact, however, the weight distribution may not be over the entire

cross-section and may be distributed along the length of the sheet which could produce even greater thickness variations.

Attempts have been made by our office to obtain from United States Steel (the manufacturer of the sheet piling) as rolled dimensions. Apparently, this data is not recorded, however, discussions with U. S. Steel personnel indicate that the thickness may vary by 7% or more. They also indicated that in general, the sheet pile web will be thicker than nominal dimension since undersized sheeting would be grounds for rejection by the purchaser.

A 7% variation in thickness would translate to a web dimension of .485" for the PSX32 sheet.

Our experience and that of other operators of ultrasonic thickness gauges is that rolled shapes and plates do vary substantially from the theoretical dimensions and in the case of steel sheet pile web thickness often as rolled dimensions are greater than the theoretical dimensions.

In addition to the metal thickness readings potential measurement of the steel sheet piling is presented. The measurements were made with a Mark V Bathycorrometer manufactured by Roxby Engineering International, Ltd.

The Bathycorrometer utilizes a silver/silver chloride reference electrode. The data presented in the report is unedited from the field.

Marine Growth:

The marine growth living on the steel sheet piling varies with both depth of water and location around the drydock. A variety of seaweeds, kelp, hairlike algae and sponges were noted along with barnacles, scallops, oysters, worms with calcareous shells, sea cucumbers, anemones and urchins.

In general, the growth was densest near the surface where sunlight and oxygen are plentiful. The growth is most abundent between Cells 11 and 17 (southeast side of drydock) where maximum sunlight and protection from strong currents is provided. In this area the kelp growth is up to 24" deep. In general on the east side of the drydock, all of the above-mentioned growth is present. Barnacles were observed from elevation +4.0 (bottom of newly-coated area) to el.-10.0 (MLLW El.0.0). In some areas the barnacles had died off and only the "footprint" of the organism remained on the coating. This barnacle kill seems to occur in random areas of 2 to 3 sq. ft. over 15% of the face of the cells and arcs on the east side. Growth in general diminishes with depth and is lightest at the mudline and practically non-existent near the mudline at the cell/arc interface where sunlight and oxygen are limited (see Photos 2 and 3).

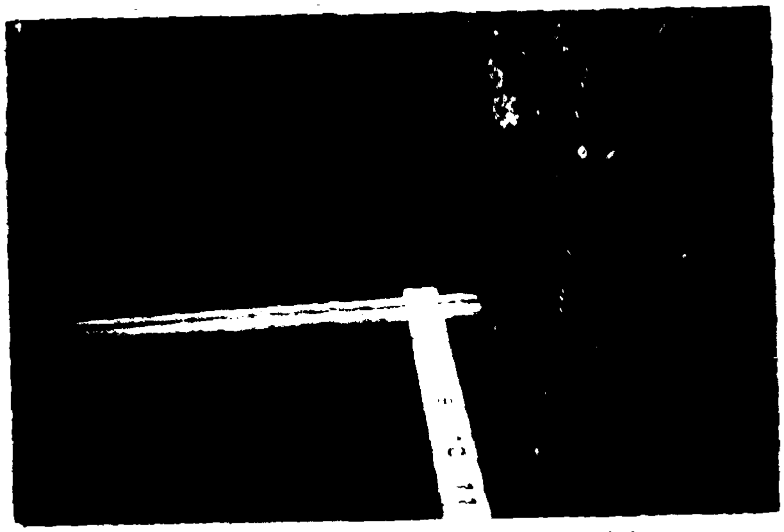
On the west side of the drydock where the cell/arc faces are shaded from extended direct sunlight by tne pier deck, there is a decrease in the kelp, seaweed and algae life. There is a marked increase in sponge growth at Cell 9 and Cell 8. Sponges cover 90%

PHOTO #2: Cell #20 Mudline (elevation -20.5), sheet 77 clockwise from wye pile.

Typical marine growth near mudline. Small anemones, hairlike algae, worms with calcareous shells.

PHOTO #3: Wye pile cell #18 - arc 14/15, mudline elevation -21.0.

Typical lack of marine growth at wye pile/mudline interface.



of the face from elevation 0.0 (MLLW) to elevation -20.0 and about 50% of the face below elevation -20.0. The barnacle kill noted on the east side was even greater on the west side. Large areas were noted where only the barnacles' "footprint" remained. Some new barnacle growth was observed on the west side.

Cell/Arc Geometry:

No anomalies in the overall cell and arc geometry were noted. In general all cells and arcs are reasonably plumb and conform with theoretical roundness. No flat spots were noted in the cells or arcs. Local cell to arc geometry is consistent with theoretical layout. The angle created between the cells and arcs at the wye piles varies, but appears to be within reasonable limits (see Photo #3).

Coating:

During the inspection the cells and arcs were being recoated between elevation +12.0 and +4.0. Although the coating contract was not complete at the time of the inspection, the new coating, in those areas which had been recoated, is sound and adhering tightly to the steel. Photo #4 illustrates the typical condition of the existing coating in the splash zone (+8.0 to +20.0).

The remaining areas of the exposed sheet piling are still protected with the original coal tar epoxy-polyamide. The condition of the original coating varied around the dock. Where coating thickness was measured it was at least equal to and often greater than the 16

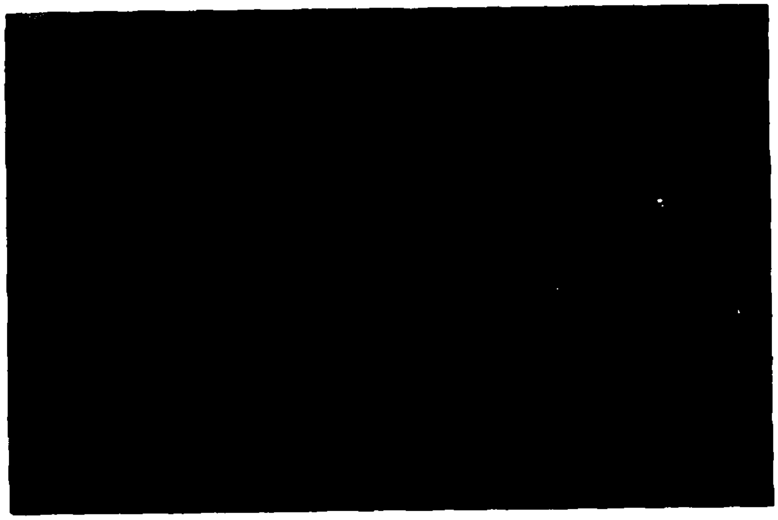


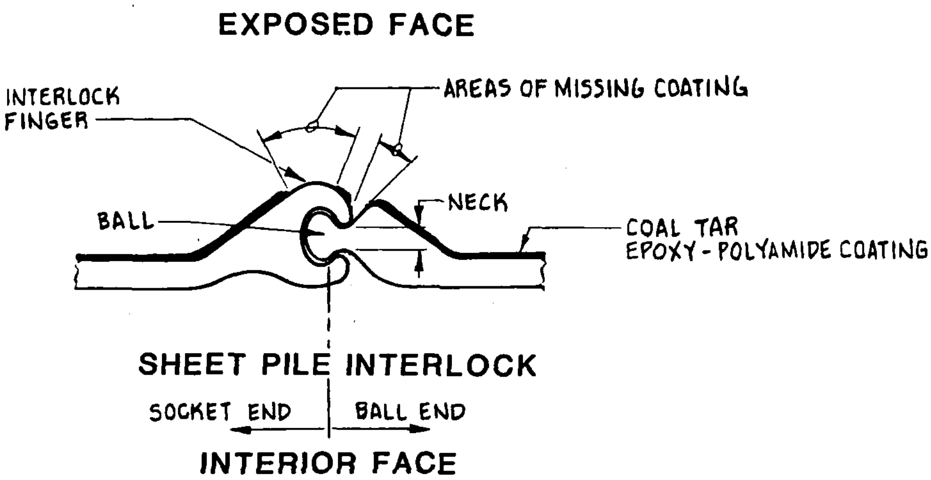
PHOTO #4: Cell #3, sheet 27 cw, splash zone elevation +8.0 to +20.0.

Typical condition of original coating in splash zone mils required by contract specification. The average thickness of the coating based on a random check was close to 23 mils dry film thickness.

The major anomaly noted was the loss of coating on the sheet pile interlocks. Specifically, the exposed curve of the finger and the intersection of the finger and the neck (see Figure 6 and Photos 5 through 9). The worst coating loss on the exposed interlock finger is at Cell 7, Cell 9 and Arc 8/9 where 50% of the coating on the finger is missing between elevation +4.0 and the mudline. At Cell 8 only 25% of the coating is missing from the interlock finger. Over the remaining cells and arcs coating loss on the interlock fingers ranges from 5 to 15 percent and is sporadically located between elevation +4.0 and the mudline. Maximum coating loss on the webs of the sheet piling was also observed between Cell 7 and Cell 9. Loss of coating was found over 3% of the web area between elevation +4.0 and the mudline. Over the remaining cells and arcs coating loss on the webs was less than 1% of the surface area (see Photo #10).

In general, coating loss at the intersection of the interlock finger and the neck (see Figure 6 and Photo #11) was observed at all sheet pile interlocks.

Coating was regularly checked for adhesion to the steel and was generally satisfactory. In areas around the observed voids where coating was missing, the adhesion to the steel is sometimes weak.



COATING CONDITION SHEET PILE INTERLOCK

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD, MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D C	
N/A		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIG NO 6

PHOTO #5: Arc 3/4, sheet 28 cw, tidal zone elevation +2.0 to +6.0.

Typical loss of coating along interlocks. Note white calcareous buildup indicating active cathodic protection.

PHOTO #6: Cell #7, sheet 31 cw, (elevation -8.0). Typical loss of coating at interlock.

PHOTO #7: Cell #8, sheet 45 cw, (elevation -20.0). Typical loss of coating at interlock.

PHOTO #8: Cell #7, sheet 40 cw, (elevation -8.0).
Loss of coating at interlock.

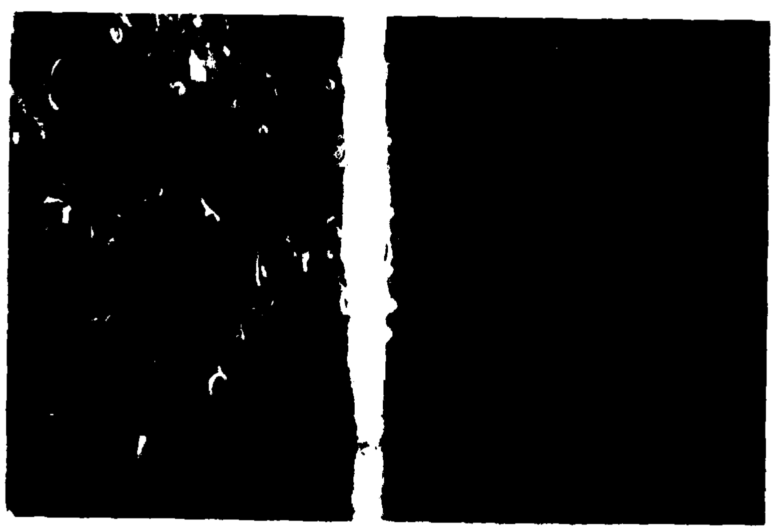
PHOTO #9: Cell #20, sheet 77 cw, (elevation -20.0).
Loss of coating at interlock.

<u>PHOTO #10:</u> Arc 16/17, sheet 15 cw, elevation -2.0

Typical area of lost coating on sheet pile web.

<u>PHOTO #11:</u> Wye pile, cell #3 - arc 2/3, elevation -20.0.

Calcareous buildup at coating void - interlock intersection. Calcareous buildup is produced by cathodic protection process.



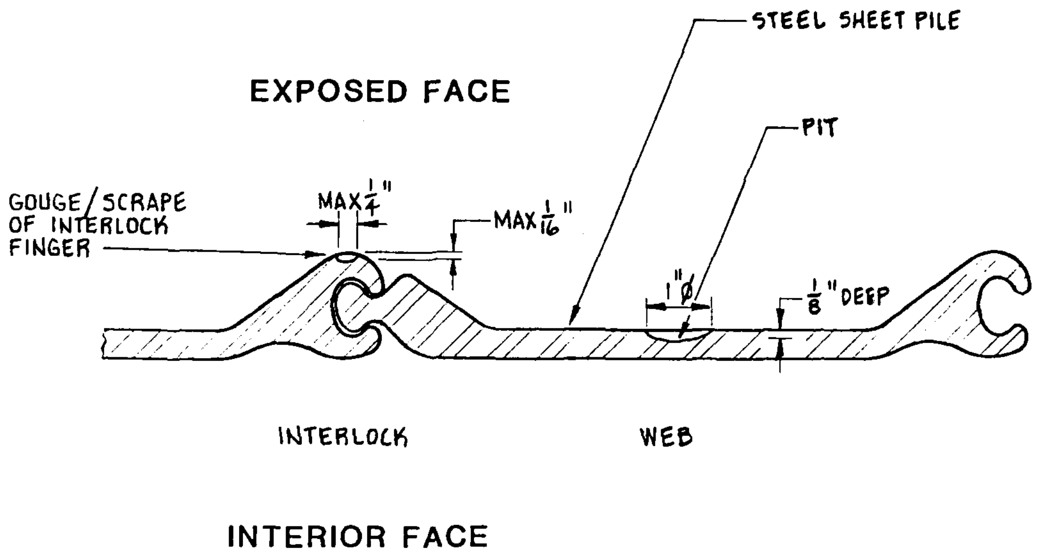
Steel Sheet Piling:

The close examination of the interconnecting wye piles and the general examination of the interlocks revealed no structural anomalies. No "unzipping" or splitting of the interlocks was observed. No unusual conditions were noted at the sheet pile/mudline interface.

The only anomalies noted on the sheet piles were some minor pitting and/or scraping of the steel. One pit, (Cell 7, Sheet 28 clockwise from wye pile, elevation -8.0) was fairly deep, approximately 1/8", and approximately 1" in diameter. The pit did not appear to be the result of corrosion but the result of a deficiency in the steel, perhaps a slag pocket (see Figure 7 and Photo #12).

The fingers of several pile interlocks have long (up to 24") gouges 1/4" wide by up to 1/16" deep (see Figure 7). These gouges are felt to be preconstruction conditions, perhaps the result of the rolling process, since in many cases the coating is intact over the gouge.

Most of the sheet piles are spliced. The splice consists of a butt weld across the web of the sheet and a splice plate covering the joint (see Photo #13). Per contract specification the splice location is staggered between adjacent sheets. The exposed area of the butt weld and the splice plate fillet weld appear to be in good condition. In most cases, the welds are coated but in those areas



OBSERVED PIT & GOUGING OF STEEL SHEET PILING

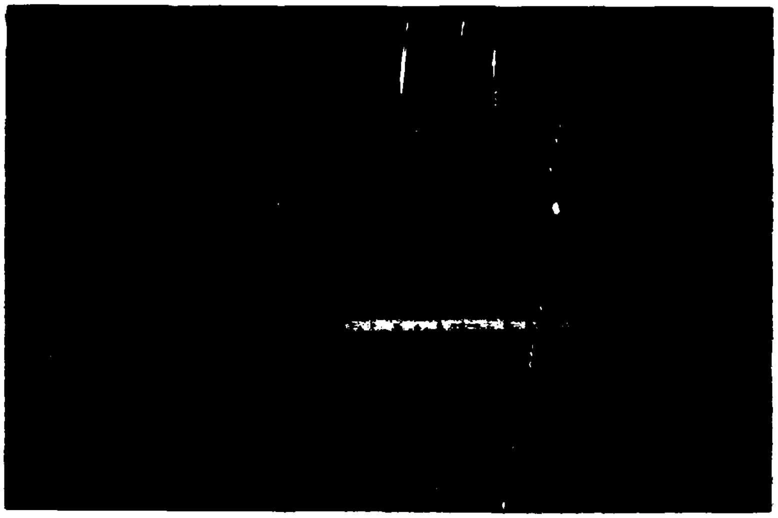
GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD, MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D C	
N/A		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIG NO 7

PHOTO #12: Cell #7, sheet 28 cw, elevation -8.0

Pit in web of sheet pile approximately 1/8" deep by 1" diameter.

PHOTO #13: Cell #8, sheet 18 cw, elevation -3.0

Typical sheet pile splice.



where the coating was missing, the welds are well-defined and no pitting or perforation was observed.

The steel thickness measurements which were taken around the dry dock indicate that little or no metal loss has occurred. Fewer than seven percent (7%) of the measurements are less than the theoretical nominal thickness of the sheet piling.

Of particular interest are the areas where coating is missing. Several thickness measurements were taken in these areas and little or no difference in thickness was observed between the coated and uncoated metal.

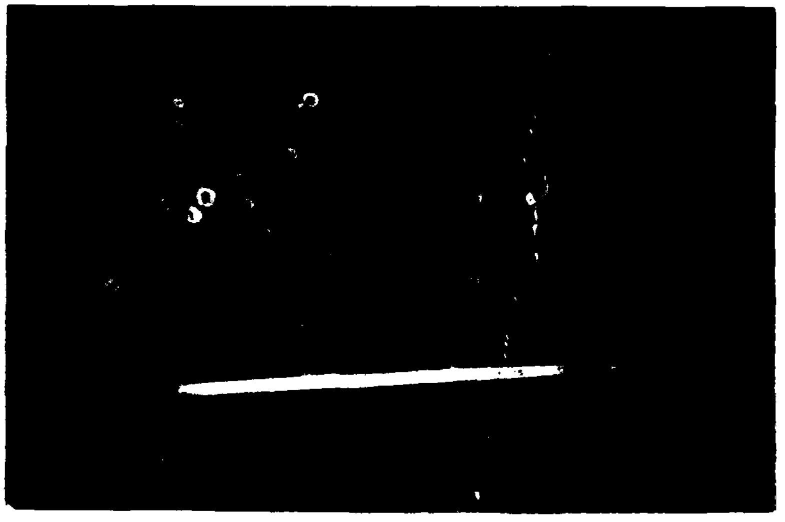
It was observed that in many areas where the coating is missing, there is a deformation of the steel. Usually this deformation is a dent or dish in the steel probably caused by impact from either a construction vessel or piece of construction equipment (see Photos 14 and 15). Usually the indentation is subtle and gives the appearance of significant metal loss. Thickness readings in these areas, however, indicated little or no metal loss.

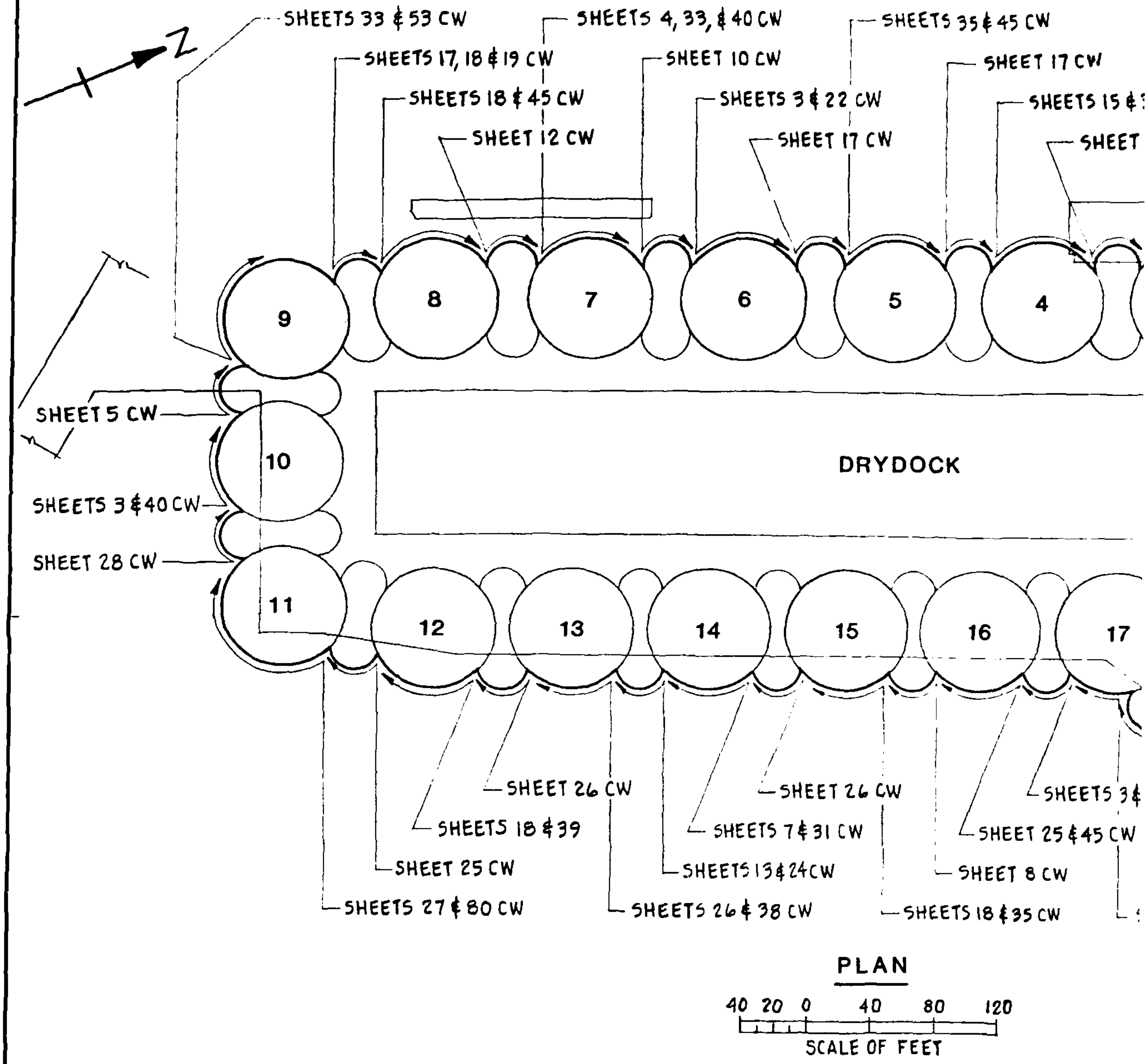
The location of the thickness measurements and the measurements themselves are presented in Figures 8 through 20. Photos 16 through 18 illustrate typical thickness measurement locations. Coating is removed to provide direct access to steel.

In reviewing the thickness measurements it is helpful to keep in mind several conditions:

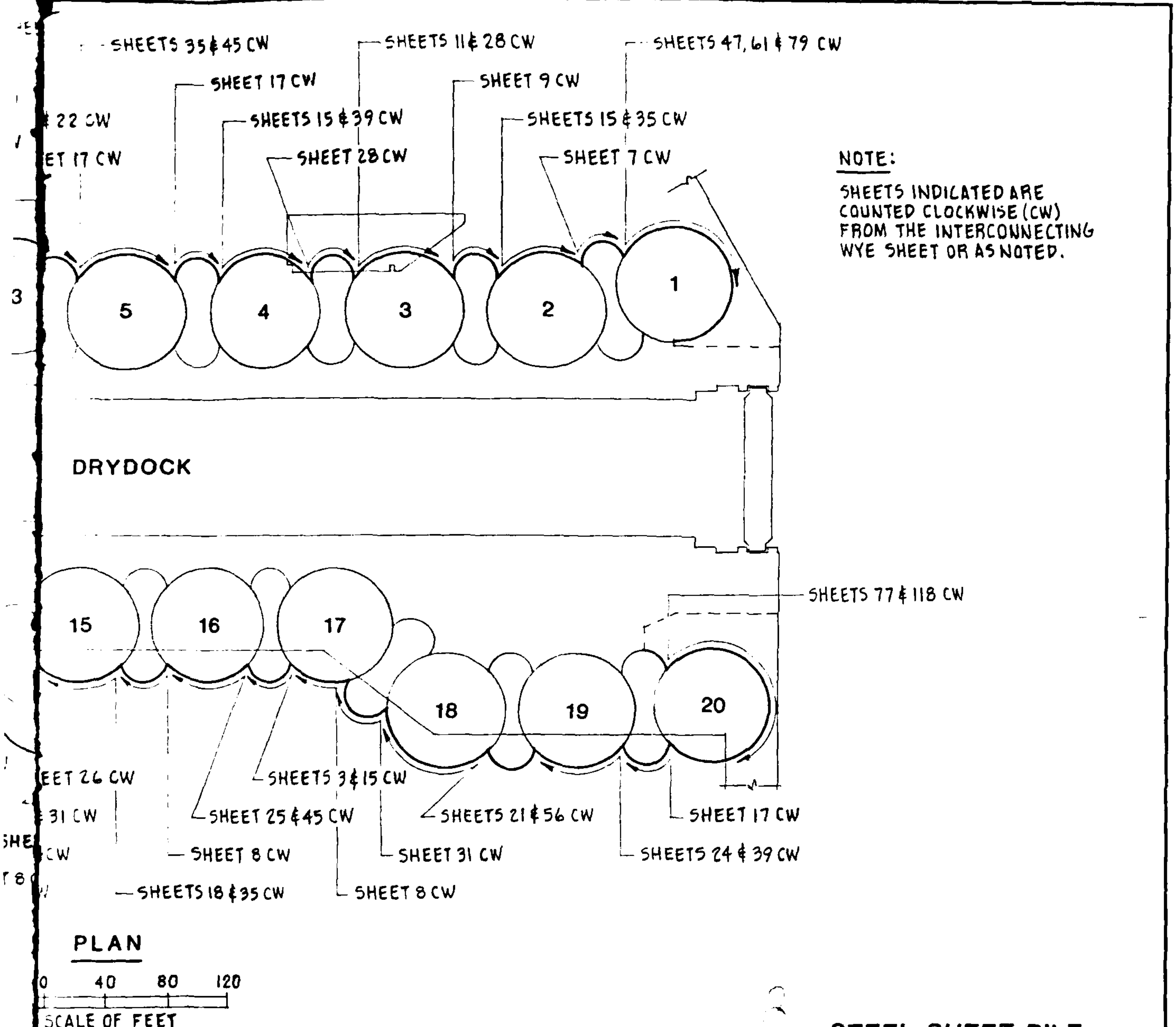
PHOTO #14: Cell #8, sheet 36, cw, elevation -12.0
Coating loss at a dent in sheet pile web.

PHOTO #15: Arc 4/5, sheet 26 cw, elevation -5.0
Coating loss at dent in sheet pile web.





REFERENCE FROM: NAVFAC DWG NO. 6042317, 6042490 & 6042491.



STEEL SHEET PILE THICKNESS MEASUREMENTS

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D C	
AS SHOWN		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIG NO 8

STEEL THICKNESS MEASUREMENTS

Cell or Arc	Sheet	Elevation (MLLW 0.0)	Thickness (in inches)
Cell #1	47th sheet clockwise from wye pile (47 cw)	+6.0	.460
		+4.0	.465
		+2.0	.470
		0.0	.460
		-2.0	.470
		-4.0	.465
		-6.0	.465
Cell #1	61 cw	+12.0	.450
		+6.0	.455
		+4.0	.445
		+2.0	.455
	79 cw	0.0	.485
		-2.0	.495
		-4.0	.460
		-5.0	.490
		-10.0	.470
		-15.0	.475
		-20.0	.460
		-25.0	.465
		-30.0	.470
		-38.5 (mudline)	.465
Arc 1/2	7 cw	+6.0	.465
		+4.0	.465
		+2.0	.460
		0.0	.460
		-2.0	.470
		-4.0	.470
		-6.0	.465
Cell #2	35 cw	+6.0	.465
		+4.0	.465
		+2.0	.470
		0.0	.470
		-2.0	.465
		-4.0	.475
		-6.0	.465
Cell #2	15 cw	+12.0	.480
		+6.0	.500
		+4.0	.490
		+2.0	.480
		0.0	.505

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D.C.	
N/A		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIGURE 9

Cell or Arc	Sheet	Elevation	Thickness
Cell #2 (cont'd)	15 cw	-2.0	.490
		-4.0	.495
		-5.0	.485
		-10.0	.505
		-15.0	.485
		-20.0	.485
		-25.0	.485
		-30.0	.475
		-35.0	.485
		-41.0 (mudline)	.480
Arc 2/3	9 cw	+6.0	.470
		+4.0	.475
		+2.0	.475
		0.0	.505
		-2.0	.505
		-4.0	.480
		-6.0	.500
Cell #3	11 cw	+6.0	.470
		+4.0	.460
		+2.0	.460
		0.0	.485
		-2.0	.485
		-4.0	.490
		-6.0	.460
Cell #3	27 cw	+12.0	.495
		+6.0	.480
		+4.0	.480
		+2.0	.485
		0.0	.505
		-2.0	.500
		-4.0	.505
		-5.0	.505
		-10.0	.500
		-15.0	.505
		-20.0	.505
		-25.0	.495
		-30.0	.505
		-35.0	.500
		-40.0	.495
		-44.0 (mudline)	.495
Arc 3/4	28 cw	+6.0	.465
		+4.0	.465
		+2.0	.470
		0.0	.465

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD, MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON, D.C.	
N/A		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIGURE 10

Cell or Arc	Sheet	Elevation	Thickness
Arc 3/4 (cont'd)	28 cw	-2.0	.490
		-4.0	.460
		-6.0	.465
Cell #4	15 cw	+12.0	.490
		+6.0	.465
		+4.0	.465
		+2.0	.470
		0.0	.505
		-2.0	.505
		-4.0	.505
		-5.0	.500
		-10.0	.500
		-15.0	.500
		-20.0	.500
		-25.0	.495
		-30.0	.500
		-35.0	.460
		-40.0	.500
		-44.0 (mudline)	--
Cell #4	39 cw	+6.0	.485
		+4.0	.480
		+2.5	.470
		+2.0	.475
		0.0	.505
		-2.0	.485
		-4.0	.500
		-6.0	.505
Arc 4/5	17 cw	+6.0	.470
		+4.0	.460
		+2.0	.460
		0.0	.490
		-2.0	.490
		-4.0	.495
		-6.0	.490
Cell #5	45 cw	+12.0	.485
		+6.0	.470
		+4.0	.465
		+2.0	.465
		0.0	.500
		-2.0	.495
		-4.0	.490
		-5.0	.470
		-10.0	.450
		-15.0	.490
		-20.0	.485
		-25.0	.490
		-30.0	.460
		-35.0	.485

GRAPHIC SCALE

N/A

CHILDS ENGINEERING CORPORATION
BOX 333
MEDFIELD MA

CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON D.C.

TRIDENT REFIT FACILITY
NAVAL SUBMARINE BASE BANGOR, WA

DRYDOCK

FIG NO
11

Cell or Arc	Sheet	Elevation	Thickness
Cell #5 (cont'd)	35 cw	+6.0	.465
		+4.0	.475
		+2.0	.470
		0.0	.505
		-2.0	.475
		-4.0	.505
		-6.0	.485
Arc 5/6	17 cw	+12.0	.470
		+6.0	.490
		+4.0	.470
		+2.0	.460
		0.0	.490
		-2.0	.505
		-4.0	.505
		-5.0	.495
		-10.0	.475
		-15.0	.505
		-20.0	.500
		-25.0	.505
		-30.0	.500
		-35.0	.505
		-40.0	.500
		-41.5 (mudline)	.500
Cell #6	3 cw	+6.0	.480
		+4.0	.475
		+2.0	.475
		0.0	.470
		-2.0	.490
		-4.0	.480
		-6.0	.515
Cell #6	22 cw	+6.0	.490
		+4.0	.485
		+2.0	.490
		0.0	.475
		-2.0	.505
Arc 6/7	10 cw	+6.0	.440
		+4.0	.465
		+2.0	.470
		0.0	.465
		-2.0	.455
		-4.0	.460
		-6.0	.495
Cell #7	40 cw	+2.0	.460
		0.0	.480

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD, MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D.C.	
N/A -29		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIG. NO. 12

Cell or Arc	Sheet	Elevation	Thickness
Cell #7 (cont'd)	40 cw	-2.0	.475
		-4.0	.450
Cell #7	4 cw	+12.0	.460
		+6.0	.460
		+4.0	.455
		+2.0	.455
		0.0	.480
		-2.0	.490
		-4.0	.490
		-5.0	.490
		-10.0	.495
		-15.0	.505
		-20.0	.495
		-25.0	.490
		-30.0	.465
		-36.0 (mudline)	.465
Cell #7	33 cw	+6.0	.475
		+4.0	.470
		+2.0	.470
		0.0	.495
		-2.0	.500
		-4.0	.485
		-5.0	.470
		-6.0	.460
Arc 7/8	12 cw	+6.0	.480
		+4.0	.485
		+2.0	.480
		0.0	.510
		-2.0	.475
		-4.0	.515
		-6.0	.495
Cell #8	18 cw	+12.0	.445
		+6.0	.465
		+4.0	.460
		+2.0	.465
		0.0	.460
		-2.0	.500
		-4.0	.505
		-5.0	.510
		-10.0	.465
		-15.0	.495
		-20 0	.505
		-25.0	.505
		-30.0	.460
		-36.0 (mudline)	.475

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D C	
N/A		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR WA DRYDOCK	FIGURE 13

Cell or Arc	Sheet	Elevation	Thickness
Cell #8 (cont'd)	45 cw	+6.0	.460
		+4.0	.455
		+2.0	.460
		0.0	.465
		-2.0 (44 cw)	.490
		-4.0	.475
		-6.0	.490
Arc 8/9	18 cw	-2.0	.445
		-3.0	.460
		-5.0	.460
Arc 8/9	17 cw	-3.0	.485
Arc 8/9	19 cw	+6.0	.460
		+4.0	.460
		+2.0	.450
		0.0	.480
		-2.0	.485
		-4.0	.480
		-6.0	.480
Cell #9	33 cw	+12.0	.455
		+6.0	.465
		+4.0	.470
		+2.0	.475
		0.0	.440
		-2.0	.430
		-4.0	.435
		-5.0	.445
		-10.0	.445
		-15.0	.450
		-20.0	.445
		-25.0	.435
		-31.0 (mudline)	.435
Cell #9	53 cw	+6.5	.465
		+4.0	.470
		+2.0	.470
		0.0	.465
		-2.0	.500
		-4.0	.500
		-6.0	.495
Arc 9/10	5 cw	+12.0	.480
		+6.0	.470
		+4.0	.465
		+2.0	.475
		0.0	.490
		-2.0	.465
		-4.0	.460

GRAPHIC SCALE

N/A

CHILDS ENGINEERING CORPORATION
BOX 333
MEDFIELD, MA

CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, D.C.

TRIDENT REFIT FACILITY
NAVAL SUBMARINE BASE BANGOR, WA

DRYDOCK

FIG. NO.
14

Cell or Arc	Sheet	Elevation	Thickness
Arc 9/10 (cont'd)	5 cw	-5.0	.470
		-10.0	.465
		-15.0	.465
		-23.5 (mudline)	.470
Cell #10	3 cw	+6.0	.460
		+4.0	.465
		+2.0	.460
		0.0	.475
		-2.0	.475
		-4.0	.450
		-6.0	.480
Cell #10	40 cw	+6.0	.465
		+4.0	.460
		+2.0	.460
		0.0	.470
		-2.0	.485
		-4.0	.475
		-6.0	.485
Arc 10/11	28 cw	+6.0	.475
		+4.0	.475
		+2.0	.475
		0.0	.495
		-2.0	.465
		-4.0	.470
		-6.0	.465
Cell #11	27 cw	+12.0	.470
		+6.0	.465
		+4.0	.470
		+2.0	.470
		0.0	.480
		-2.0	.490
		-4.0	.460
		-5.0	.485
		-10.0	.490
		-15.0	.460
		-19.5 (mudline)	.445
Cell #11	80 cw	+6.0	.470
		+4.0	.470
		+2.0	.465
		0.0	.490
		-2.0	.485
		-4.0	.485
		-6.0	.470
Arc 11/12	25 cw	+6.0	.460
		+4.0	.460

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON DC	
N/A		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIGURE 15

Cell or Arc	Sheet	Elevation	Thickness
Arc 11/12 (cont'd)	25 cw	+2.0	.470
		0.0	.465
		-2.0	.495
		-4.0	.485
		-6.0	.450
Cell #12	18 cw	+12.0	.470
		+6.0	.465
		+4.0	.470
		+2.0	.475
		0.0	.490
		-2.0	.495
		-4.0	.490
		-5.0	.480
		-10.0	.455
		-16.5 (mudline)	.480
Cell #12	39 cw	+6.0	.470
		+4.0	.480
		+2.0	.450
		0.0	.465
		-2.0	.490
		-4.0	.490
		-6.0	.465
Arc 12/13	26 cw	+6.0	.480
		+4.0	.485
		+2.0	.480
		0.0	.475
		-2.0	.480
		-4.0	.505
		-6.0	.495
Cell #13	38 cw	+12.0	.460
		+6.0	.470
		+4.0	.465
		+2.0	.460
		0.0	.485
		-2.0	.490
		-4.0	.490
		-5.0	.485
		-10.0	.485
		-15.0	.485
		-21.5 (mudline)	.470
Cell #13	26 cw	+6.0	.475
		+4.0	.475
		+2.0	.470
		0.0	.480
		-2.0	.465

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D C	
N/A		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIG NO 16

Cell or Arc	Sheet	Elevation	Thickness
Cell #13 (cont'd)	26 cw	-4.0	.500
		-6.0	.485
Arc 13/14	13 cw	+12.0	.465
		+6.0	.470
		+4.0	.460
		+2.0	.470
		0.0	.490
		-2.0	.490
		-4.0	.460
		-5.0	.450
		-10.0	.490
		-15.0	.460
		-19.0 (mudline)	.490
Arc 13/14	24 cw	+6.0	.465
		+4.0	.465
		+2.0	.495
		0.0	.500
		-2.0	.500
		-4.0	.490
		-6.0	.480
Cell #14	7 cw	+12.0	.455
		+6.0	.470
		+4.0	.475
		+2.0	.465
		0.0	.500
		-2.0	.500
		-4.0	.495
		-5.0	.500
		-10.0	.495
		-15.0	.500
		-21.0 (mudline)	.495
Cell #14	31 cw	+6.0	.475
		+4.0	.470
		+2.0	.470
		0.0	.495
		-2.0	.485
		-4.0	.460
		-6.0	.495
Arc 14/15	26 cw	+6.0	.470
		+4.0	.475
		+2.0	.490
		0.0	.495
		-2.0	.500
		-4.0	.480
		-6.0	.470

Cell or Arc	Sheet	Elevation	Thickness
Cell #15	35 cw	+12.0	.465
		+6.0	.460
		+4.0	.455
		+2.0	.480
		0.0	.480
		-2.0	.460
		-4.0	.480
		-5.0	.490
		-10.0	.490
		-15.0	.490
		-20.0 (mudline)	.485
Cell #15	18 cw	+6.0 (17 cw)	.480
		+4.0	.475
		+2.0	.475
		0.0	.500
		-2.0	.495
		-4.0	.500
		-6.0	.500
Arc 15/16	8 cw	+12.0	.470
		+6.0	.470
		+4.0	.475
		+2.0	.470
		0.0	.460
		-2.0	.450
		-4.0	.455
		-6.0	.455
Cell #16	25 cw	+12.0	.460
		+6.0	.440
		+4.0	.455
		+2.0	.460
		0.0	.465
		-2.0	.475
		-4.0	.475
		-5.0	.485
		-10.0	.460
		-15.0	.450
		-20.5 (mudline)	.480
Cell #16	45 cw	+6.0	.460
		+4.0	.480
		+2.0	.470
		0.0	.455
		-2.0	.475
		-4.0	.460
		-6.0	.460
Arc 16/17	3 cw	+6.0	.445
		+4.0	.445
		+2.0	.445

GRAPHIC SCALE

N/A

CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD MA

CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON D C

TRIDENT REFIT FACILITY
NAVAL SUBMARINE BASE BANGOR, WA
DRYDOCK

FIGURE 18

Cell or Arc	Sheet	Elevation	Thickness
Arc 16/17 (cont'd)	3 cw	0.0	.460
		-2.0	.460
		-4.0	.455
		-6.0	.455
Arc 16/17	15 cw	+6.0	.430
		+4.0	.430
		+2.0	.430
		0.0	.485
		-2.0	.450
		-4.0	.465
		-6.0	.480
Cell #17	8 cw	+12.0	.485
		+6.0	.470
		+4.0	.475
		+2.0	.470
		0.0	.500
		-2.0	.505
		-4.0	.470
		-5.0	.485
		-10.0	.505
		-17.0 (mudline)	.500
Arc 17/18	31 cw	+6.0	.440
		+4.0	.445
		+2.0	.440
		0.0	.485
		-2.0	.495
		-4.0	.490
		-6.0	.495
Cell #18	21 cw	+12.0	--
		+6.0	.470
		+4.0	.450
		+2.0	.455
		0.0	.485
		-2.0	.460
		-4.0	.480
		-5.0	.485
		-10.0	.485
		-15.0 (mudline)	.465
Cell #18	56 cw	+6.0	.455
		+4.0 (sheet 55 cw)	.450
		+2.0	.480
		0.0	.510
		-2.0	.500
		-4.0	.470
		-6.0	.500

GRAPHIC SCALE

N/A

CHILDS ENGINEERING CORPORATION
BOX 333
MEDFIELD, MA

CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, D.C.

TRIDENT REFIT FACILITY
NAVAL SUBMARINE BASE BANGOR, WA

DRYDOCK

FIGURE 19

Cell or Arc	Sheet	Elevation	Thickness
Cell #19	24 cw	+12.0	.485
		+6.0	.470
		+4.0	.460
		+2.0	.470
		0.0	.465
		-2.0	.475
		-4.0	.485
		-5.0	.475
		-10.0	.470
		-15.0	.475
		-19.0 (mudline)	.460
Cell #19	39 cw	+6.0	.495
		+4.0	.500
		+2.0	.495
		+1.0	.500
		-2.0	.470
		-4.0	.475
		-6.0	.470
Arc 19/20	17 cw	+12.0	.485
		+6.0	.485
		+4.0	.475
		+2.0	.475
		0.0	.495
		-2.0	.485
		-4.0	.465
		-6.0	.465
Cell #20	118 cw	+12.0	.475
		+6.0	.440
		+4.0	.445
		+2.0	.445
		0.0	.460
		-2.0	.470
		-4.0	.465
		-5.0	.455
		-10.0	.470
		-15.0	.430
		-20.5 (mudline)	.440
Cell #20	77 cw	+12.0	.490
		+6.0	.470
		+4.0	.485
		+2.0	.475
		0.0	.485
		-2.0	.465
		-4.0	.460
		-6.0	.490

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D C	
N/A		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIG NO 20

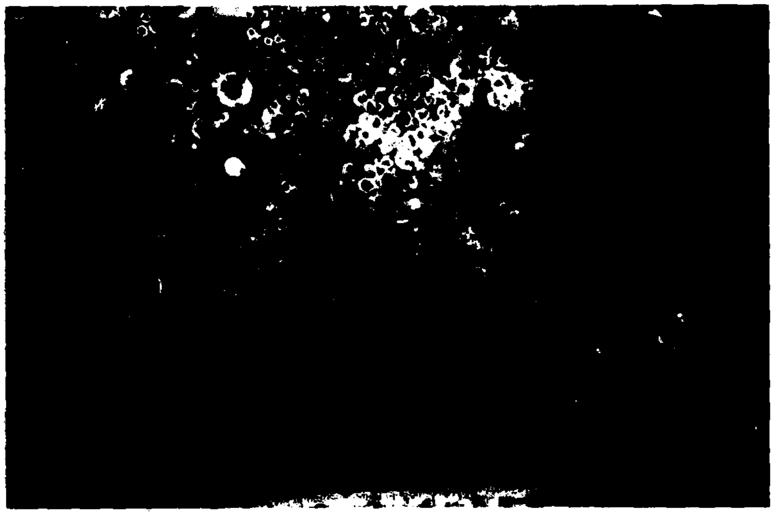


PHOTO #16: Cell #8, sheet 18 cw, elevation -5.0

Typical steel thickness measurement location.

PHOTO #17: Arc 19/20, sheet 17 cw, elevation -4.0

Typical steel thickness measurement location.

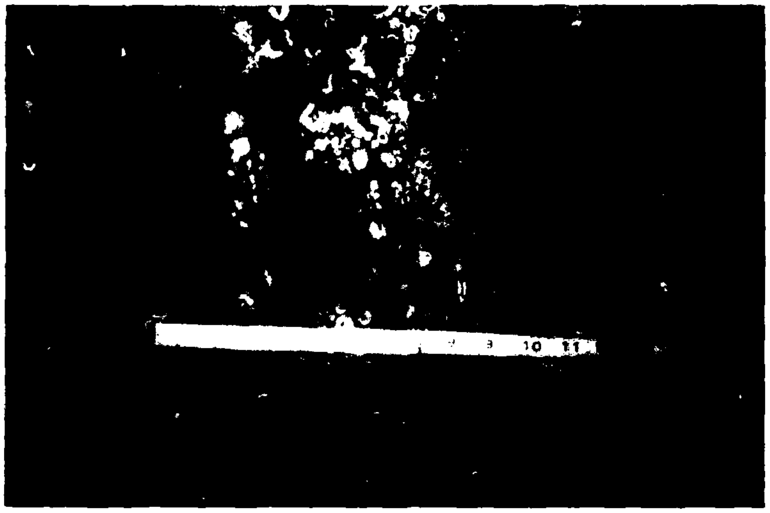


PHOTO #18: Cell #15, sheet 35 cw, elevation -15.0

Typical steel thickness measurement location.

1) Above and below splice locations there may be a significant difference in metal thickness. This is a result of the fact that two different sheet piles were joined and may have had significantly different rolled thicknesses.

2) If no corrosion has taken place the sheet piles will generally be thicker than the theoretical nominal dimensions since thicknesses less than nominal are grounds for rejection and probably wouldn't have been installed.

In addition, the reader should be aware of the cell structure function and the design criteria. The following statement summarizes both:

"2. Among the various factors considered was the function of the sheet pile cells after completion of drydock construction. It was noted that the primary purpose of the cells was to allow dewatering of the site and that during the construction phase stresses in the sheet piles reached a maximum. Upon completion of construction, the cells serve to confine fill supporting a portion of working deck area adjacent to the drydock. Stresses in the steel sheet piles are then much lower than during the construction stage. This reduction in stress means that the piles have a substantial surplus thickness. This surplus, which can be considered a 'corrosion allowance', is as shown below. Note that this surplus thickness is the amount that can be sacrificed without the stress in the steel exceeding the design stress, so that a substantial factor of safety will still remain.

Depth	Elevation (MLLW = 0.0)	Surplus Metal
Midtide	+5.4	.381"
Midtide - 2'	+3.4	.312
Midtide - 20'	-14.6	.281
Midtide - 40'	-34.6	.224
Midtide - 60'	-54.6	.167 "*

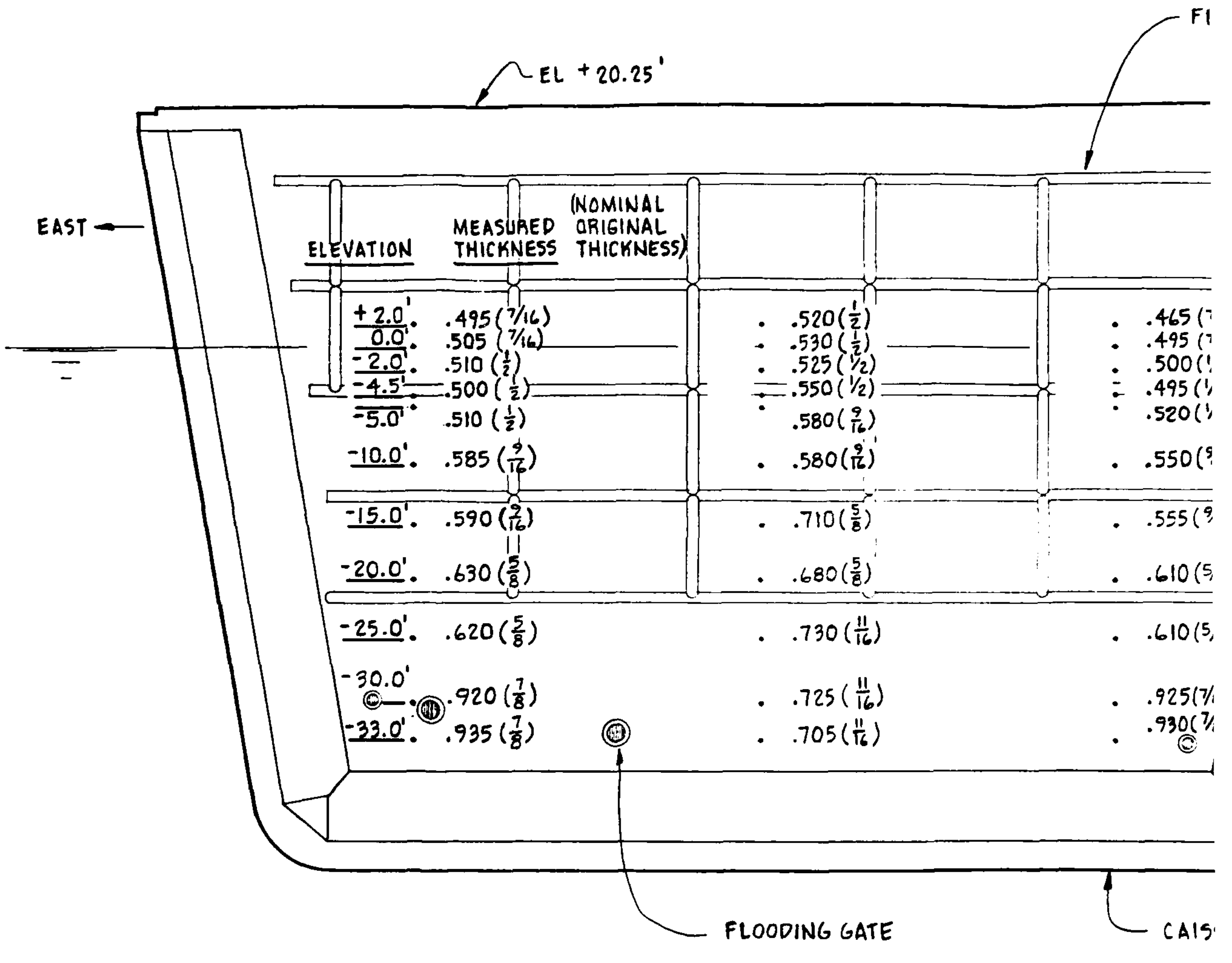
*Reference 2 - Correspondence of November 30, 1979 from Officer in Charge of Construction, TRIDENT to Commander, Naval Sea Systems Command (PMS-396).

Caisson:

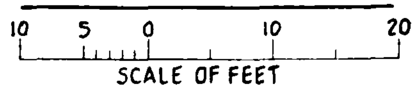
No anomalies were noted during the inspection of the exterior of the exposed face of the caisson. The coating is intact and adhering to the steel over greater than 99% of the surface. Metal thickness measurements were taken at three locations on the face of the caisson (see Figure 21). The exposed caisson seal appears to be in excellent condition (see Photo 19). The exposed face of the caisson is also protected from corrosion by sacrificial anodes. The anodes are still intact and due to the condition of the coating have lost little or no material (see Photo 20).

Abutment:

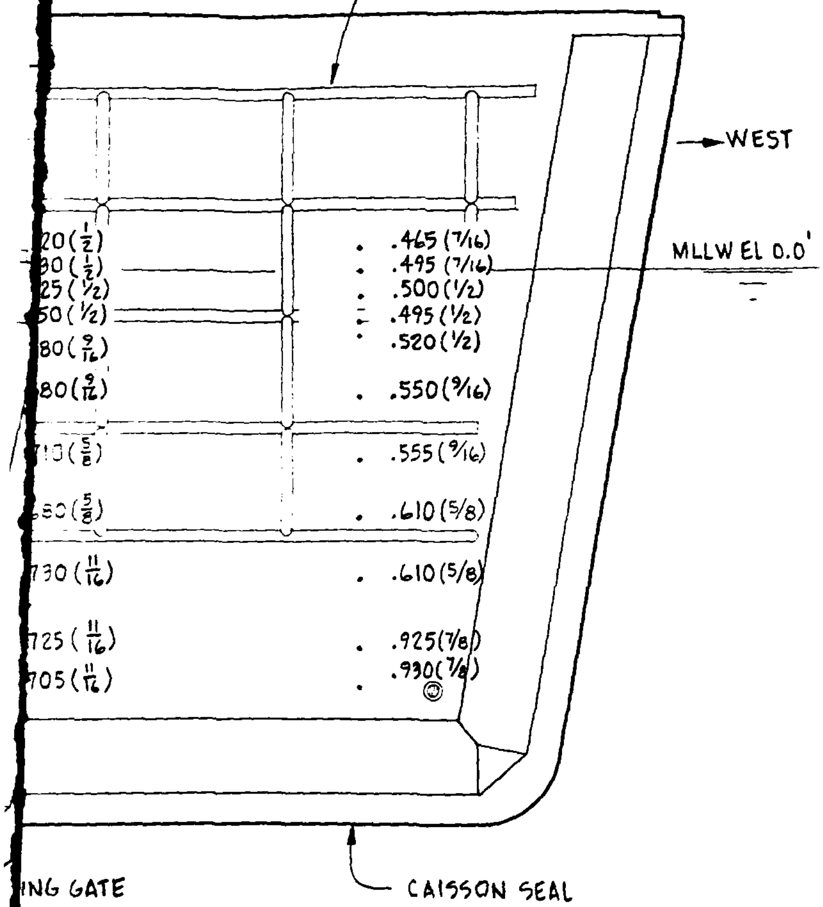
The concrete abutment and caisson seat were closely examined. No unusual conditions were noted. In general, the concrete is sound when struck with a chipping hammer. No anomalies were noted at the abutment/mudline interface. Some small holes, probably the result



CAISSON
STARBOARD ELEVATION

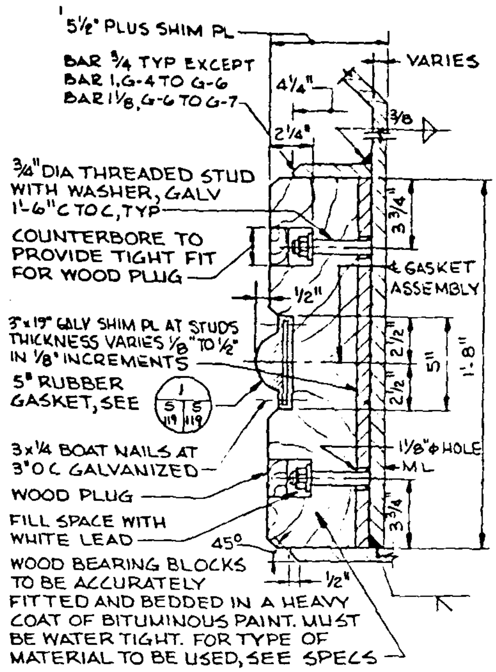


REFERENCE FROM: NAVFAC DWG NO. 6042539.



SON
ELEVATION

10 20
FEET



GASKET ASSEMBLY DETAIL

CAISSON SEAL

STEEL THICKNESS MEASUREMENTS EXPOSED FACE OF CAISSON

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D C	
AS SHOWN		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIG NO 21

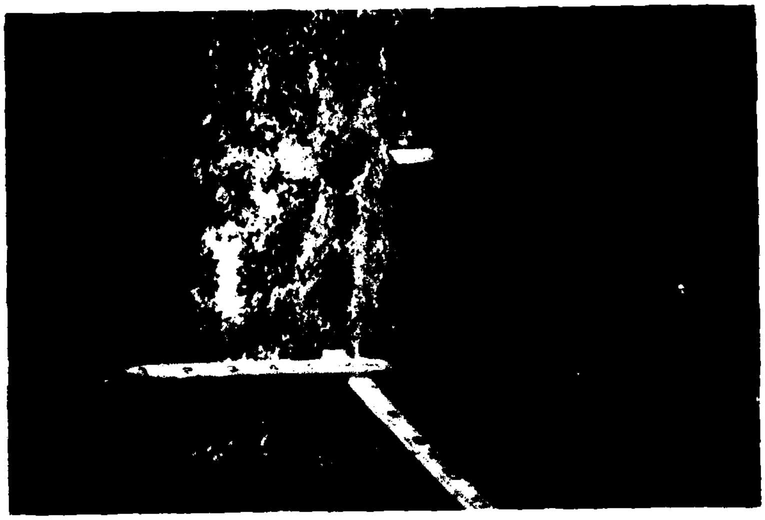


PHOTO #19: West side of caisson, elevation -15.0
Typical condition of caisson seal.

PHOTO #20: West side of caisson, elevation -20.0
Typical caisson anode.

of insufficient vibration of the concrete during construction, were noted at the steel sheet pile/concrete connection of the west abutment (see Photo #21).

Cathodic Protection:

The exposed face of the steel sheet piling associated with the drydock is protected from corrosion by both the coal tar epoxy-polymide coating and an impressed current cathodic protection system. Examination of the impressed current system indicates that there are 83 anodes (see Figure 22) which provide protection for the cells and arcs.

All of the anodes appeared to be functioning at the time of the inspection. The anodes are covered with a gray-brown film (lead peroxide) which is produced when the anodes are active and provides a barrier which prolongs the anodes' life.

Steel sheet pile potential measurements using a silver/silver chloride reference electrode were taken at various locations around the drydock (see Figures 23 through 25). The measurements were taken at some of the same locations along each sheet as the metal thickness measurements.

During the inspection it was noted that when the coating was removed from the sheet piles, within two or three days a bright white (calcareous) film would develop over the bare metal (see Photo 22 and 23). In addition, most of the old bare spots have a dull gray

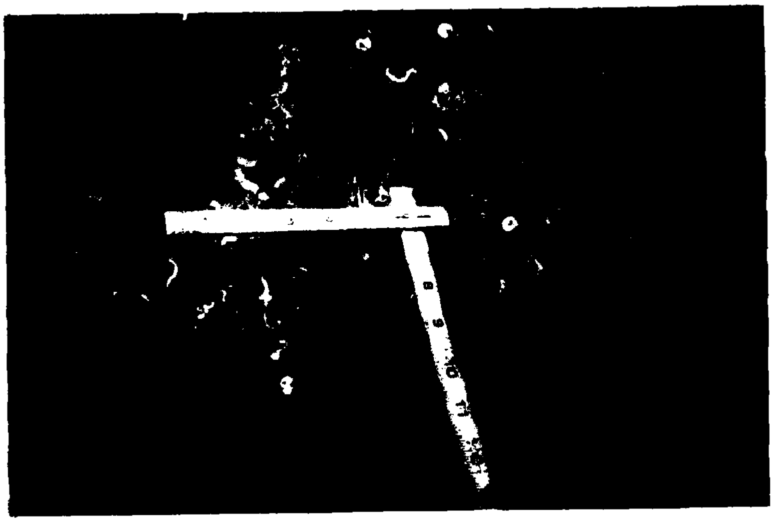
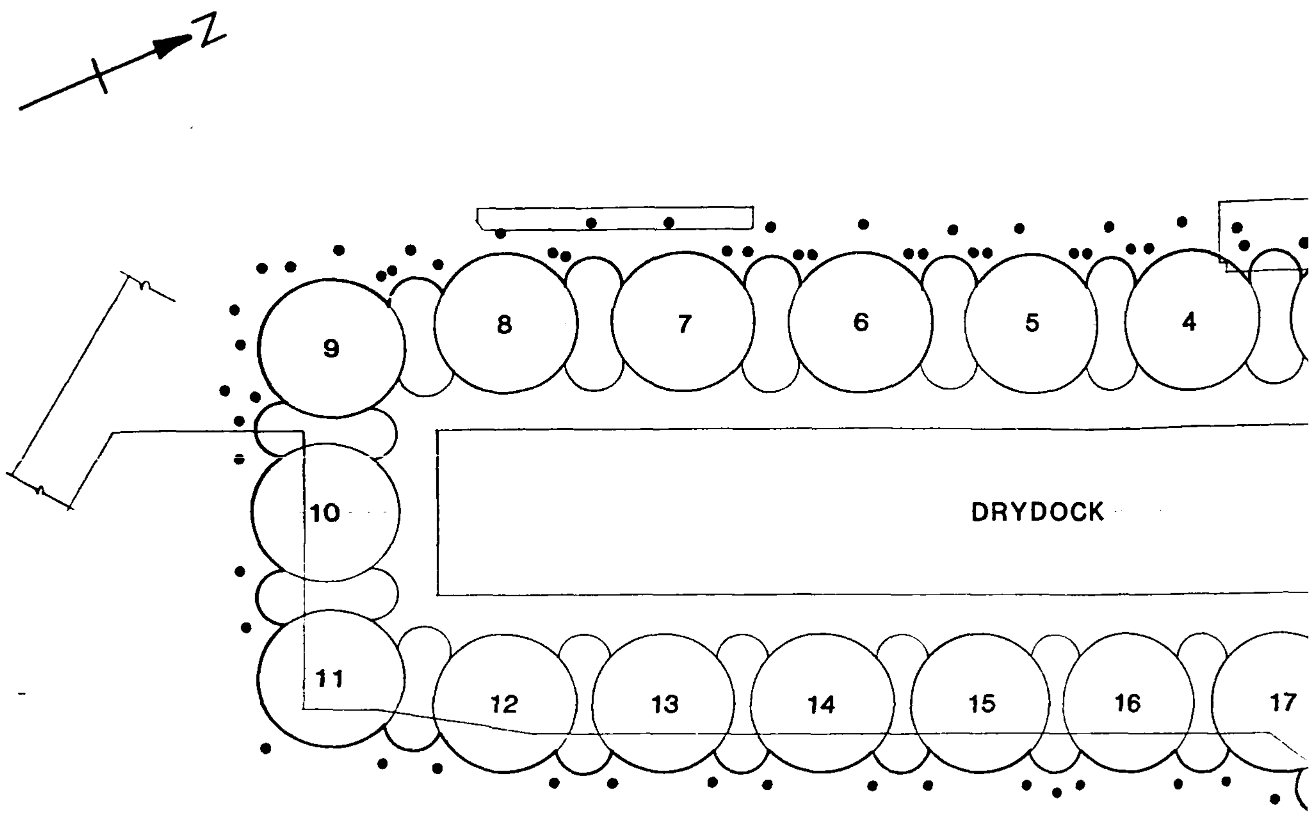
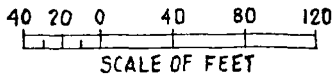


PHOTO #21: Cell #1/abutment interface, elevation -15.0

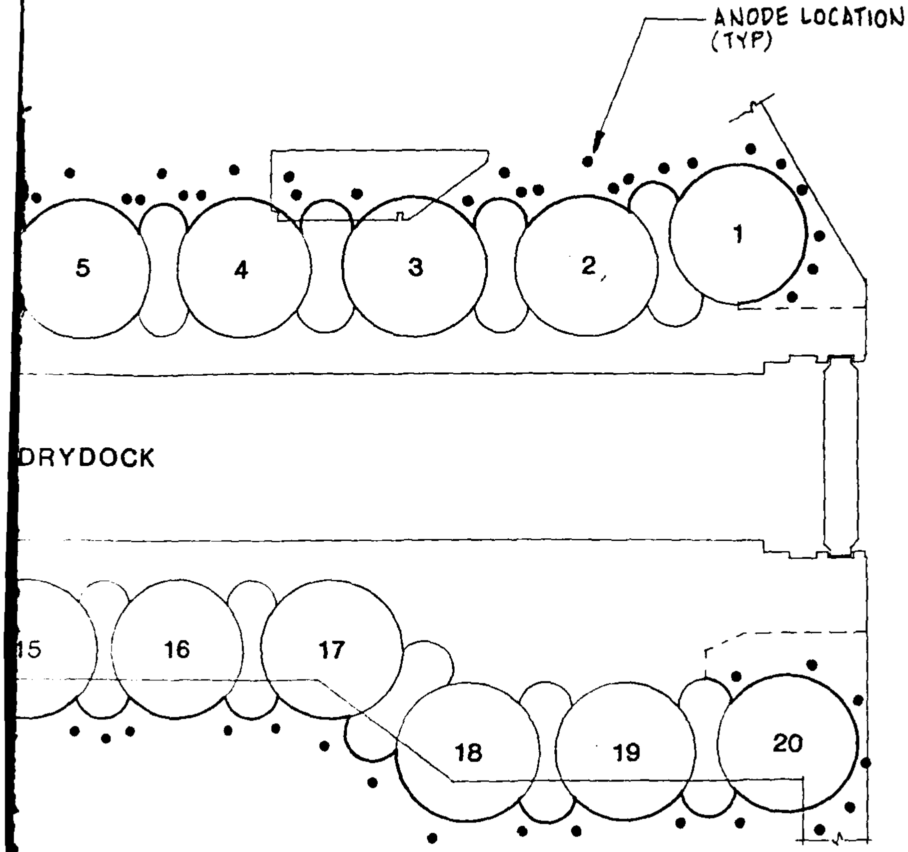
Cosmetic spalling at steel sheet pile/ concrete abutment interface.



PLAN



REFERENCE FROM: PAN AM "CATHODIC PROTECTION SYSTEM FOR TRIDENT DRYDOCK."



PLAN

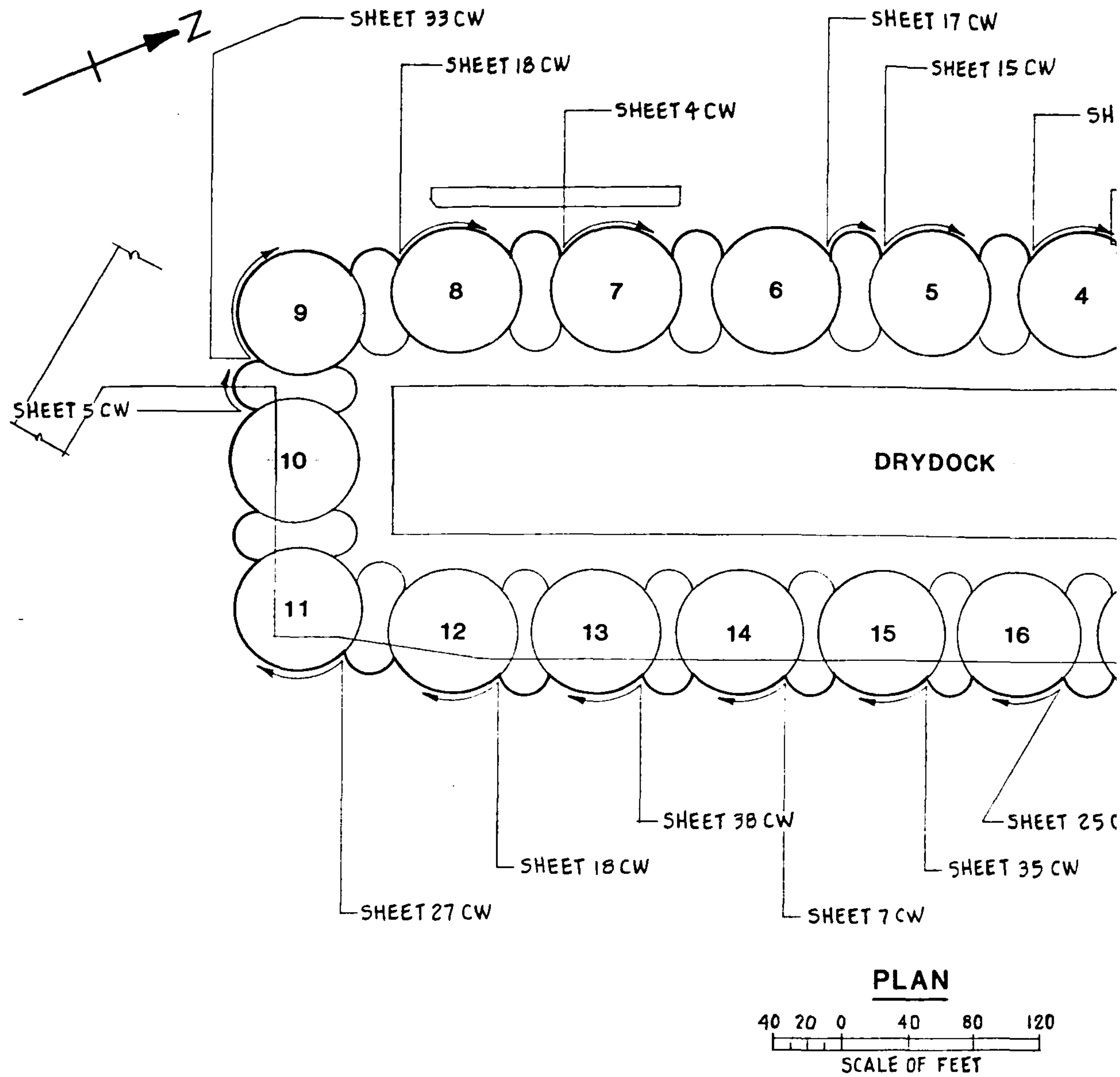
40 80 120

SCALE OF FEET

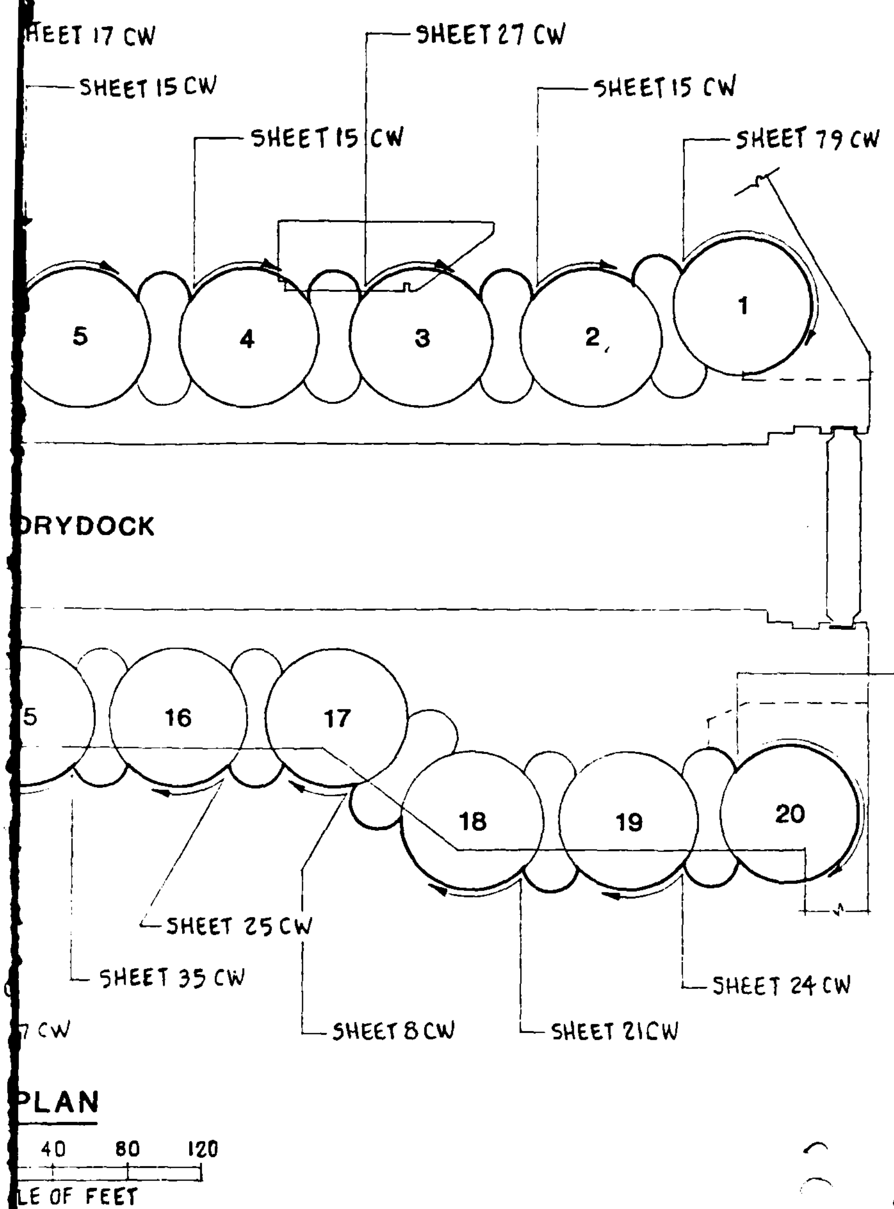
CATHODIC PROTECTION ANODE LOCATION

CK ,"

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD, MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON	
AS SHOWN		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIG NO 22



REFERENCE FROM: NAVFAC DWG NO. 6042317, 6042490 & 6042491.



NOTE:

SHEETS INDICATED ARE COUNTED CLOCKWISE (CW) FROM THE INTERCONNECTING WYE SHEET OR AS NOTED.

STEEL SHEET PILE POTENTIAL MEASUREMENTS

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D C	
AS SHOWN		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIG NO. 23

STEEL SHEET PILE POTENTIAL MEASUREMENTS

Silver/Silver Chloride Reference Electrode

Cell or Arc	Sheet	Elevation (MLLW 0.0)	Potential (mV)
Cell #1	79th sheet clockwise from wye pile (79 cw)	-4.0	880
		-15.0	900
		-38.5 (mudline)	900
Cell #2	15 cw	-4.0	1120
		-15.0	1150
		-41.0 (mudline)	1110
Cell #3	27 cw	-2.0	1100
		-15.0	1090
		-44.0 (mudline)	1080
Cell #4	15 cw	-2.0	1150
		-15.0	1160
		-40.0	1120
Cell #5	45 cw	-2.0	1110
		-15.0	1150
		-35.0	1120
Arc 5/6	17 cw	-2.0	1130
		-15.0	1140
		-41.5 (mudline)	1110
Cell #7	4 cw	-2.0	1080
		-15.0	1080
		-36.0 (mudline)	1060
Cell #8	18 cw	-2.0	1060
		-15.0	1060
		-36.0 (mudline)	1050
Cell #9	33 cw	-2.0	1100
		-10.0	1100
		-31.0 (mudline)	1060
Arc 9/10	5 cw	-2.0	1110
		-15.0	1110
		-23.5 (mudline)	1110
Cell #11	27 cw	-2.0	1090
		-10.0	1090
		-19.5 (mudline)	1110

GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON D C	
N/A		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, W. DRYDOCK	FIG NO 24

Cell or Arc	Sheet	Elevation	Potential
Cell #12	18 cw	-2.0	1080
		-10.0	1080
		-16.5 (mudline)	1100
Cell #13	38 cw	-2.0	1100
		-10.0	1100
		-21.5 (mudline)	1100
Cell #14	7 cw	-2.0	1100
		-10.0	1090
		-21.0 (mudline)	1100
Cell #15	35 cw	-2.0	1100
		-10.0	1100
		-20.0 (mudline)	1110
Cell #16	25 cw	-2.0	1130
		-10.0	1130
		-20.5 (mudline)	1120
Cell #17	8 cw	-2.0	1150
		-10.0	1140
		-17.0 (mudline)	1140
Cell #18	21 cw	-2.0	1160
		-10.0	1160
		-15.0 (mudline)	1150
Cell #19	24 cw	-2.0	1140
		-15.0	1140
		-19.0 (mudline)	1130
Cell #20	118 cw	-2.0	1150
		-15.0	1130
		-20.5 (mudline)	1110

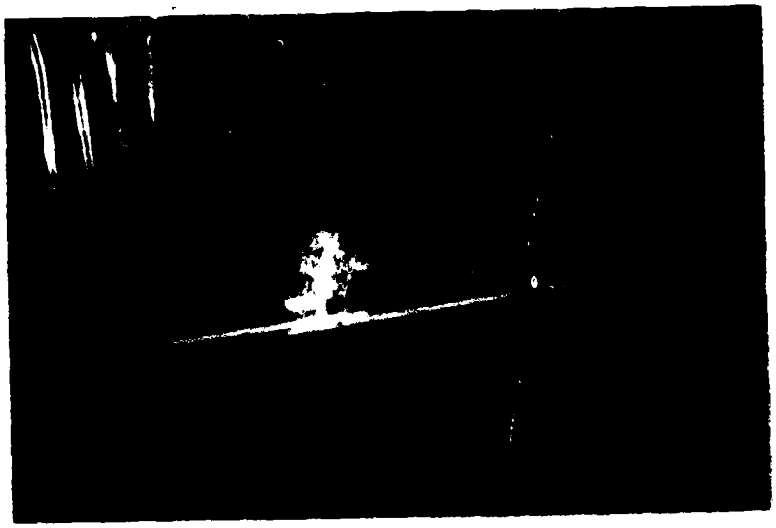
GRAPHIC SCALE	CHILDS ENGINEERING CORPORATION BOX 333 MEDFIELD, MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON, D.C.	
N/A		TRIDENT REFIT FACILITY NAVAL SUBMARINE BASE BANGOR, WA DRYDOCK	FIGURE 25

<u>PHOTO #22:</u> Arc 19/20, sheet 17 cw, elevation -4.0

Bright white calcareous deposit on steel thickness measurement location.

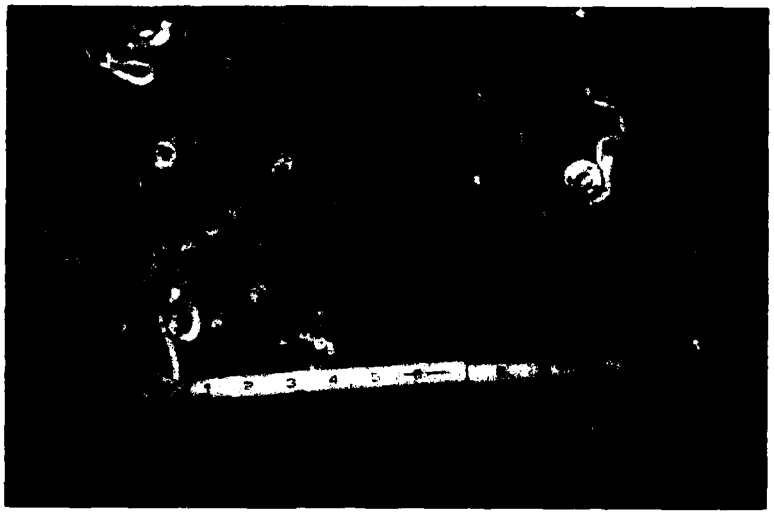
<u>PHOTO #23:</u> Cell #18, sheet 21 cw, elevation -15.0

Bright white calcareous deposit on steel thickness measurement location.



film over the metal (see Photos 24 and 25). Both of these observations are indications that the cathodic protection system is functioning.

In one area, where the anode is located within 24" of the sheet piles, a thick white calcareous buildup was observed where the coating was missing at the interlock (see Photo 26). The gray/brown coating on the anodes is also evident in this photo.



<u>PHOTO #24:</u> Cell #5, sheet 37 cw, elevation -7.0

Dull gray film over bare metal.

<u>PHOTO #25:</u> Cell #7, sheet 39 & 40 cw, elevation -12.0

Dull gray film over bare metal. Note bright white film at edges, where coating was recently chipped away.

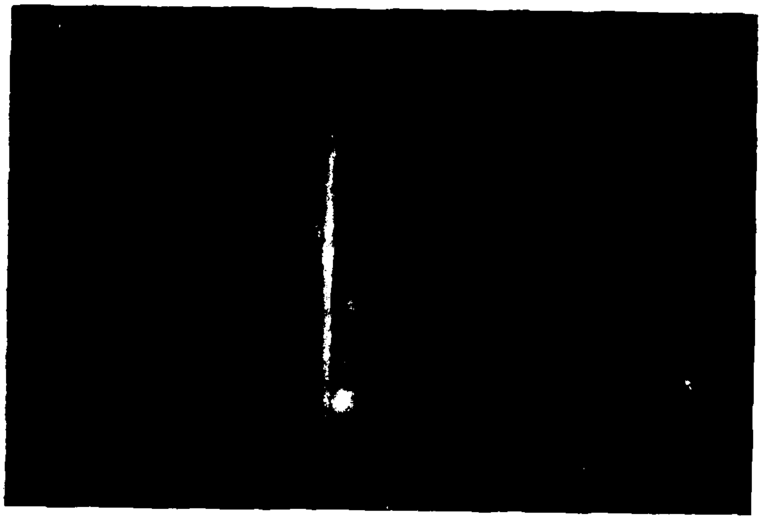


PHOTO #26: Wye pile at Cell #3 - arc 2/3, elevation -20.0

Bright white calcareous buildup at sheet pile interlocks. Note gray/brown film on anode.

4.1.3 STRUCTURAL CONDITION ASSESSMENT

The steel sheet piling, caisson, and abutment are in excellent condition. The observed conditions are consistent with that of other structures of similar age and construction which are exposed to the same environment.

The marine growth is typical of the Hood Canal area and appears to have no effect on the drydock structure.

The observed loss of marine growth, particularly barnacles, has been addressed in several reports. In general, these reports conclude that the observed growth kill may have been caused by a malfunction of the impressed current cathodic protection in conjunction with unusual environmental conditions. Of importance to the drydock structure is that the growth kill had no effect on the integrity of the steel sheet piling. The potential harm, however, which could be caused to the drydock structure and may be related to a marine growth kill would be a cathodic protection system malfunction. A condition where the cathodic protection system is over-protecting can cause damage to the coating which would reduce the protection presently afforded the steel sheet piling.

The observed loss of coating from the steel sheet piling has no effect on the structural integrity of the drydock. The impressed current cathodic protection system was installed to supplement the coating as the primary corrosion protection mechanism for the submerged sections of the steel sheet piling. During the inspection it appeared that the cathodic protection system was providing protection to the uncoated steel.

Several of the areas of missing coating can be explained. The loss of coating at the sheet pile interlock where the finger meets the neck is the result of scraping during installation. The coating voids at the dented or dished areas are probably the result of impact which caused a crack in the coating and eventual loss. The coating loss on the exposed face of the interlock finger is the most difficult to explain. This coating loss could be the result of construction where an external template was used to position sheets during driving and which scraped the coating. It is also possible that during construction, barges were docked against the cells and wave action caused them to chaff against the interlocks, thereby scraping off the coating. Another cause could be high stress in the interlocks developed during cell dewatering, which resulted in expansion of the steel (strain) and caused the coating to crack and eventually fall off. The loss of coating may well be attributed to a combination of these.

The steel sheet piling is generally in excellent condition. Steel thickness measurements indicate that no significant loss of metal has taken place. Less than seven percent (7%) of the thickness measurements were lower than nominal sheet pile thickness. Twenty five percent (25%) of the measurements which are less than nominal thickness were found to occur on one (1) pile (Cell 9, sheet 33 cw), which indicates that this pile was probably rolled thin.

Two other sheet piles (Arc 16/17, sheet 15 cw and Cell #20, sheet 118 cw) account for another twenty-five percent (25%) of the thickness measurements less than nominal while the remaining are randomly scattered.

One of the measurements which was less than the nominal sheet pile thickness was located in an area which was dented and where the coating was missing (Arc 8/9, sheet 18 cw, elevation -2.0). The thickness of the steel at this location is .445" or 8 mils less than the theoretical nominal thickness. The noted metal loss is insignificant from a structural standpoint since surplus metal at this elevation is in the neighborhood of .300" (see Reference #2).

The caisson is in very good condition. No structural deficiencies were noted during the inspection and the shell steel thickness measurements indicate that no significant metal loss has occurred.

The concrete abutments and caisson seat are in excellent condition. The concrete is sound and there are no signs of spalling or deterioration. The minor cosmetic conditions noted are of no structural significance.

The impressed current cathodic protection system is functioning and is providing corrosion protection for the submerged portion of the steel sheet piling. Potential measurements taken at the time of inspection indicate that the steel is polarized to the open-circuit anode potential of local action cells. In fact, the readings indicate that some over-protection is being provided. Over-protection can be hazardous if it is extreme and so much hydrogen is generated that the coating is harmed (blistered or cracked), however, this does not appear to be the case with the sheet piles. The bright white calcareous buildup observed on the steel after the coating was removed also indicates that the cathodic protection system is functioning. If minimum protection was being achieved, calcareous accumulation would be slower and probably never appear as bright white but as a dull gray film due to the accumulation of impurities.

Those areas which were without coating at the time of the inspection exhibited a dull gray film which indicates that the system has been functioning properly for some period of time prior to the inspection.

4.1.4 RECOMMENDATIONS

No repairs to the structures are recommended at this time. We recommend continuation of the maintenance program which was observed during the inspection. Of particular importance is the monitoring and regular adjustment of the impressed current cathodic protection system. We also recommend that the current policy of recoating the splash zone of the structures when the original coating deteriorates be continued.

To monitor the current maintenance program and the effectiveness of the cathodic protection system, the steel sheet piling should be re-inspected in three (3) years. This report should be used as a "baseline" for all future inspections. The estimated cost for re-inspection is $40,000.00 (see Appendix).

COST OF RE-INSPECTION

Based on use of this report as a baseline and current prices.

Field - Labor	480 hrs. @ $40/hr.	$19,200
Equipment	20 days @ $120/day	2,400
Travel and Per Diem		6,400
Report - Labor	250 hrs. @ $40/hr.	10,000
Reproduction		2,000
		$40,000

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