Fig. 18

Antenna Silos Open Cut Excavation,
Shoring of Slope, Site 1A

Fig. 19

Open Cut Excavation of Powerhouse,
Control Center Showing Lava Cap, Site 1C

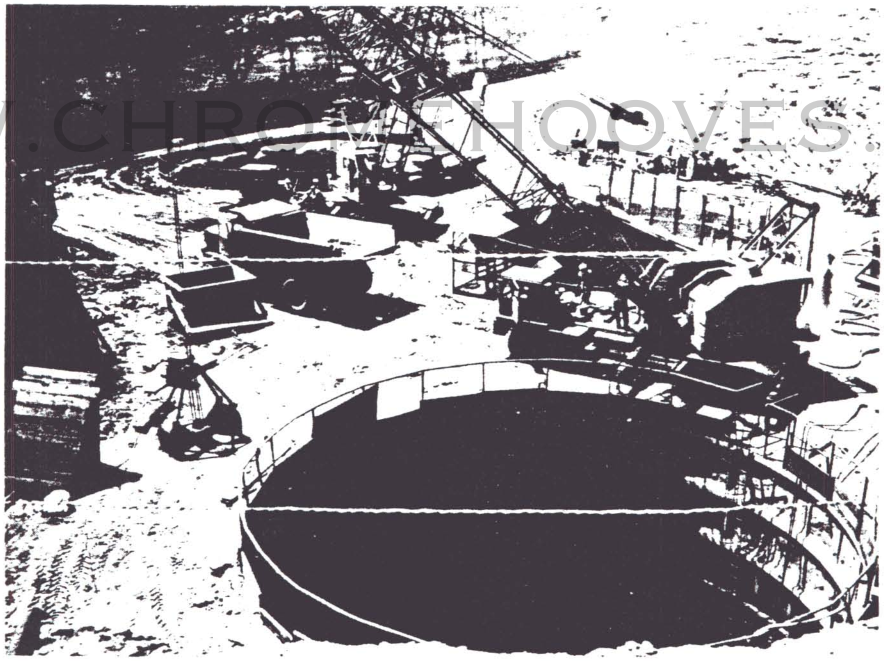

Fig. 20

Shafting Operations Showing Equipment,
Launcher #1, Site 1A

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Fig. 21

Rock Bolt Hole Drilling, Site 1A

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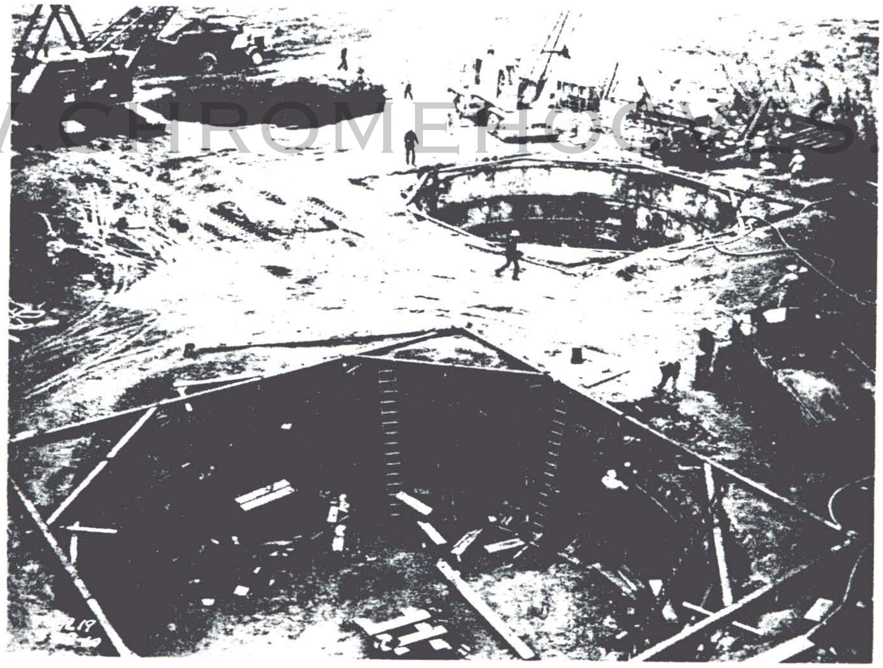

Fig. 22
Shafting Operations Showing Steel Ring Beams, Gunite, Launcher #1, Site 1A

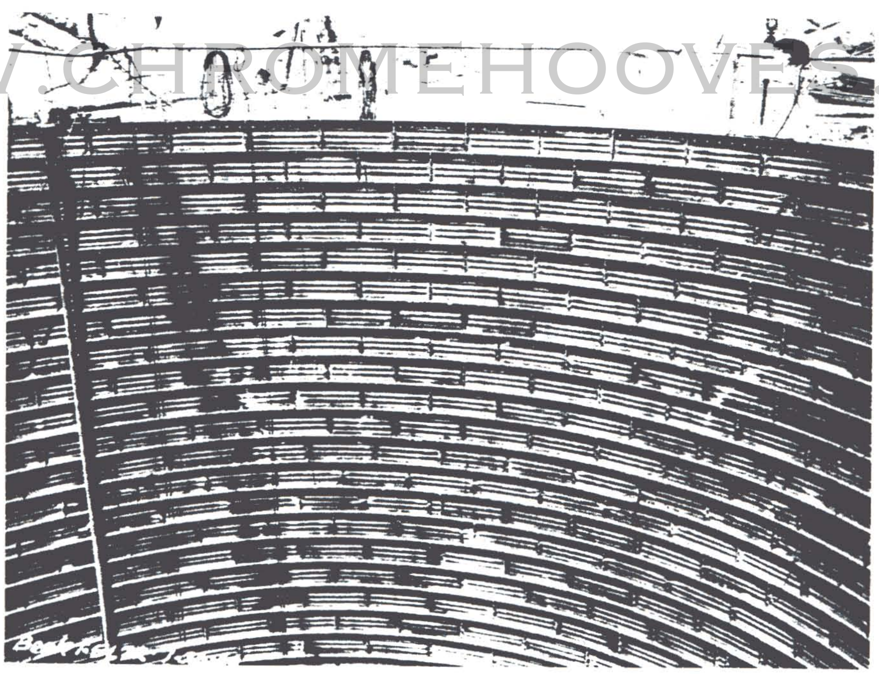

Fig. 23
Liner Plate, Missile Silo #2, Site 1A

Manitowoc 60 ton crawler type crane, two American 40 ton truck cranes and a Cat 977 loader with ripper. (See Figures 10and 20) At Sites 1A and 1C, Gardner-Denver and Ingersoll-Rand air tracks were used for rock bolt hole drilling. (See Figure 21) A nine cubic yard loading bucket was used in lifting muck from shafts. (See figure 22) Euclid end dump trucks were used to haul muck to waste piles.

At Site 1A the hardened granite appeared at start of shafting operations. Sequence of operations was drilling, loading and blasting, mucking, and setting of steel ring beams. At Site 1A ring beams used with wood lagging, wire mesh and gunite were part of the contractor's method of shoring. (See Figure 20) At Sites 1B and 1C, steel ring beams on 5'2" centers with wire mesh and gunite were used in accordance with a design prepared by the contractor and made a part of the contract by change order. At Site 1A the contractor proposed the use of a sectional liner plate which was used by modification to contract (See Figure 23) in lieu of the smooth plate. The sectional liner plate joints required sealing with Products Research Company's 250 rubber calk or equal. The smooth liner plate required welding at the seams.

Changed conditions of the foundation rock in Missile Silo #2, Site 1A, resulted in a design change of the foundation slab. The change consisted of eliminating the rock bolts and increasing reinforced concrete slab thickness to 9 feet. The reason for the change was that the granite was considered unsuitable to provide adequate anchoring of the rock bolts. At Site 1A rock bolts were required to anchor the foundation slabs of all other structures in order to compensate for hydrostatic pressure. (See Figures 24 and 25 and 26) In the Missile Silo, one hundred rock bolts were required. These were 2 3/4" round bolts, 28 feet 6 inches long, 27 feet of which were grouted into the hole with non-shrink grout. The end embedded into the concrete had upset end to 3" diameter. Rock bolts for other structures were 2" round bolt, with lengths of 22', 23' 6" or 28'6". (See Figure 27) All rock bolts were threaded at each end. The bottom nut was tack welded and at top end washers were used with the nut.

At Site 1A in Missile Silo #1, steel ring beams were used to 30 feet below top of shaft. In Missile Silos #2 and #3, the softer granite extended to greater depths than in Missile Silo #1. The ring beams in Missile Silo #2 were set to the bottom of the shaft and the spacing of a portion changed to 2 feet 6 inches. In Missile Silo #3 ring beams were set to 70 feet below top of shaft. A portion of the ring beams was spaced at 2 feet 6 inches.

During installation of the liner plate at Site 1A, buckling of the plate caused some delay. (See Figure 28) The buckling apparently was caused by grout shrinkage which allowed water to enter behind liner plate, thus creating hydrostatic pressure of sufficient force to buckle the plates.

Shafting operations began at Site 1A on 10 March 1960. Initial work was done in Launcher #1 and final work, completed on 25 June 1960, was done in Launcher #3.

The sequence of operations was the same at Sites 1B and 1C as at Site 1A, except that at Site 1B only occasional drilling and blasting were needed to remove boulders. Some minor buckling of the liner plate occurred at Site 1C.

The start of shafting operations at Site 1B was on 19 April 1960 and completion on 27 June 1960. The start of shafting operations at Site 1C was in June 1960 and completion in August 1960.

BACKFILL

The backfilling was accomplished by the Prime Contractor. Operations began in September 1960 at Sites 1A and 1B and in October 1960 at Site 1C. At all sites the stockpile materials from the open cut excavation furnished sufficient backfill material. DW 21's and D8 Dozer with Sheepsfoot Roller were heavy equipment used. Around the structures gasoline motor powered vibratory compactors were used. (See Figure 29)

Few problems were encountered. The greatest difficulty was in the handling of over optimum material during inclement weather. Close construction control was maintained to insure that contractor obtained the required 90 per cent of maximum density at optimum moisture content in the fill or the 95 per cent of maximum density adjacent to structures.

One specification requirement was changed, in that rock up to 20 inches was allowed in the fill material with the exception that within 4 feet of structures, material had to meet original specification requirements. (See Figure 30) The specifications required that rock be reduced to a maximum size of 2/3 the thickness

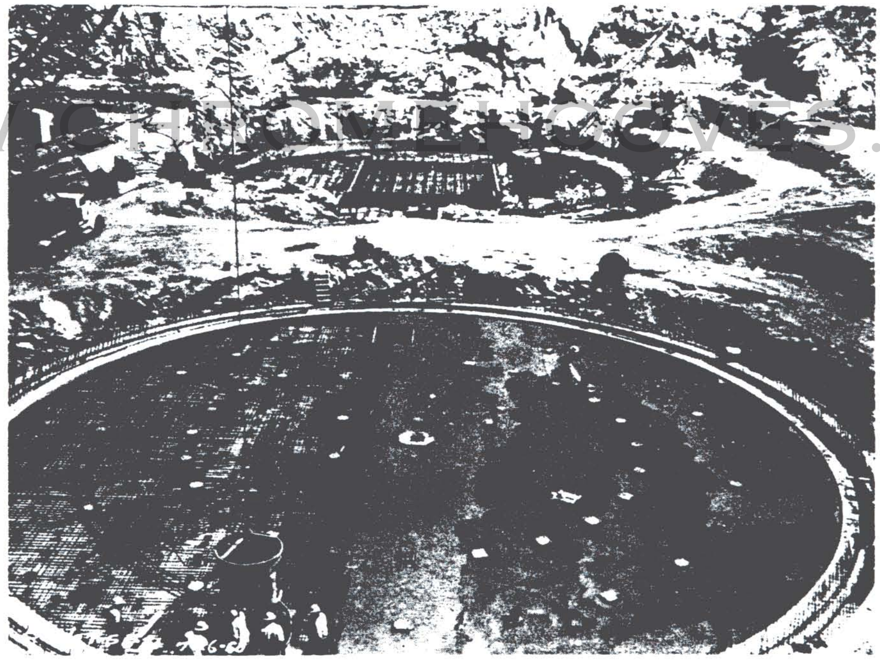

Fig. 24

Rock Bolts, Control Center, Site 1A

Fig. 25

Rock Bolts, Control Center, Site 1A

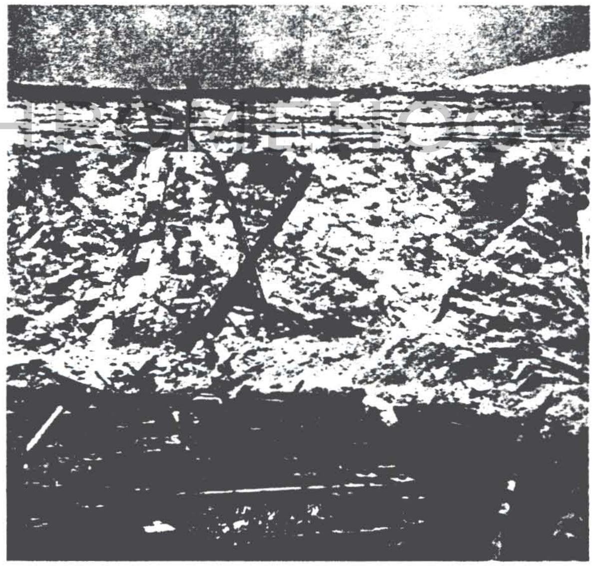

Fig. 26

Rock Bolts, Site 1A, Control Center

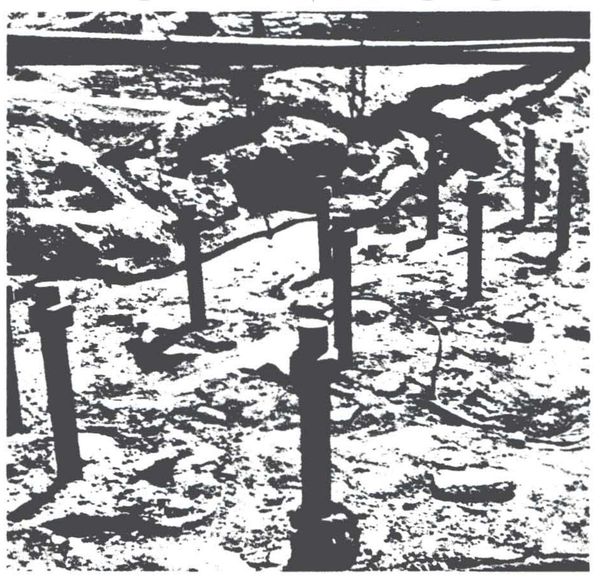

Fig. 27

Rock Bolts, Site 1A

Fig. 28

Buckled Liner Plate, Site 1A, Missle Silo

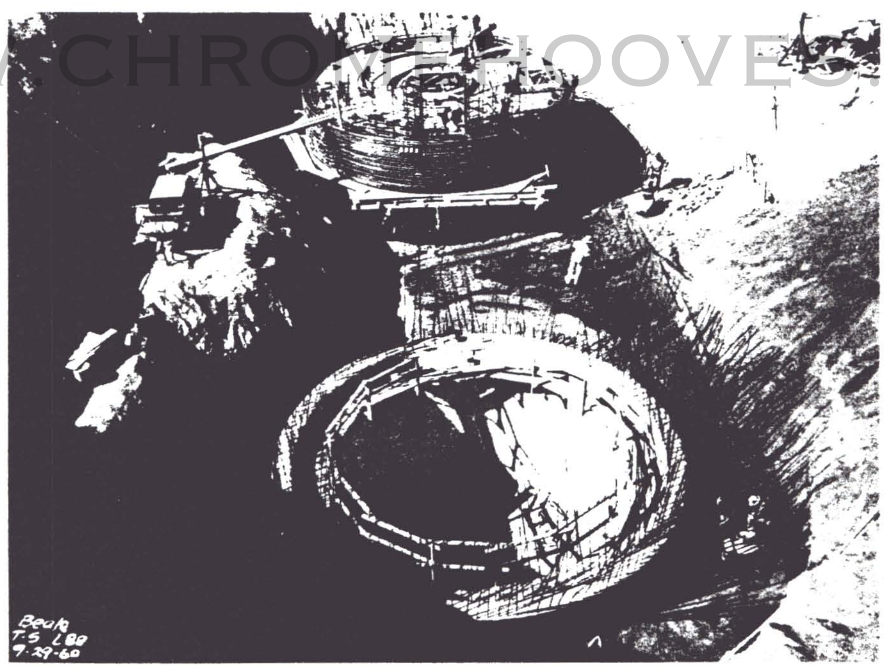

Fig. 29

Compacting Backfill Antenna Silos, Site 1A

Fig. 30

Backfill Showing Rock, Site 1C

Fig. 31

Tunnel Backfill, Site 1A,
Between Tunnel Junction #10 and Antenna Terminal

of the layer in which the rock was placed. Layer thickness was specified as not to be placed in layers exceeding 8" in thickness.

At Site 1C the quantity of rock excavated from the open cut excavation was much greater than that excavated at Sites 1A and 1B. Much of this rock was utilized in the backfill.

The specification requirements for tunnel backfill were waived at Sites 1A and 1B, in that at Site 1A (See Figures 31 and 32) sand backfill was used underneath and up to spring line and at Site 1B, because of the suitability of the granular material, sand was not used. Specifications required that sand be backfilled beneath, above and on each side of structures.

Fig. 32

Tunnel Backfill, Site 1A

Fig. 33

Concrete Batch Plant, Site 1A

6. CONCRETE OPERATIONS

CONCRETE PLANT

The Prime Contractor accomplished all of the concrete work.

At each site a portable, automatic-controlled Noble Batch Plant with an 850 barrel storage cement silo was set up. (See Figure 33) The capacity of the plant was 80 cubic yards per hour. The sand and aggregate were dumped into the weighing batch hopper by means of conveyor belt. From the weighing hoppers, the sand, gravel and cement were dumped onto a conveyor belt and conveyed to the loading hopper. Water was metered by volume from scale room and piped to loading hopper. The air entraining agent was measured into a cylinder and by air, released into the loading hopper.

During concrete placement there were one to eleven transit mix trucks used on pours. An average of three to four trucks was used per pour.

Cranes using concrete buckets were utilized in placing concrete. (See Figures 34 and 35)

CONCRETE MATERIALS

Approximately 90,000 cubic yards of concrete were used. The specifications required strengths of 5000,3750,3000,2500 and 2000 pounds per square inch. Maximum sizes of aggregate used were 1½" and 3/4".

The source of fine and coarse aggregates depended upon the location of the sites. At Site 1A aggregates were supplied by Richter and Harms from their Bear River plant near Sheridan, California. At Site 1B aggregates were furnished by Matthews Ready Mix Inc. from their Feather River plant at Gridley, California. At Site 1C sand was furnished by Richter and Harms from their Dry Creek plant near Pintz, California and coarse aggregate was supplied by Mack Rock and Sand Company near Stony Creek.

The aggregates were hauled to the sites by truck, and stock-piled.

The Calaveras Cement Company, San Andreas, California, supplied the cement. All cement was Type II and was hauled to the site by cement trucks.

The air entraining agent and curing compound, Edoco, were supplied by Edoco Technical Products Company, Long Beach, California.

Ice for cooling concrete mixtures was supplied by local ice companies. An ice storage room was built at each batch plant.

The Corps of Engineers South Pacific Division Laboratory designed the concrete mixes. The Class A designs are listed. Most of the concrete was Class A.

SITE 1A

1 1/2" Maximum

Cement	4.99 sacks/cu.yd.
Sand	33% by volume
Gravel	67% by volume
Air	4.0% by volume
Water	5.5 gal/sack

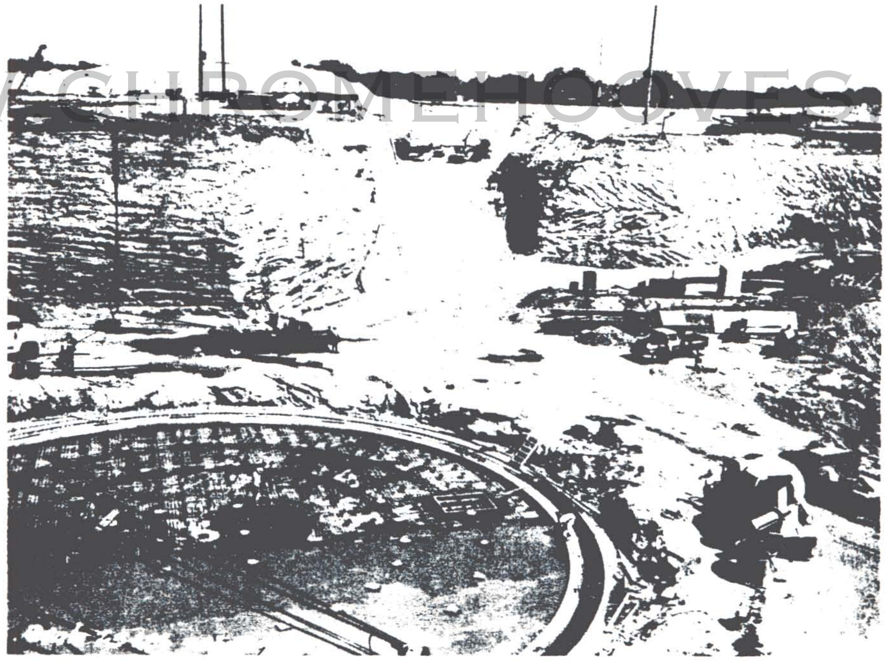

Fig. 34
Concrete Placement, Control Center, Site 1A

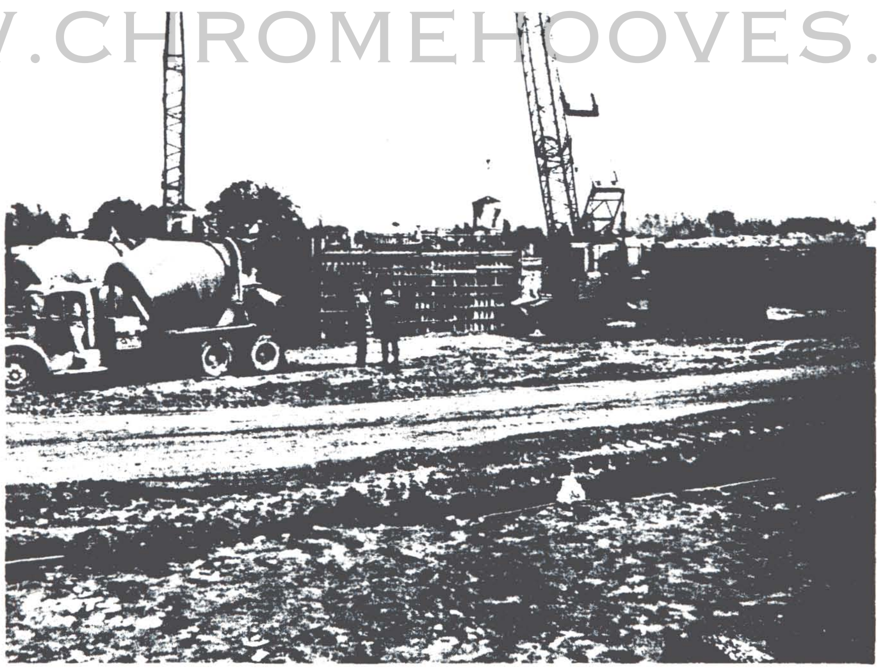

Fig. 35
Concrete Placement, Missile Silo #2, Site 1A

SITE 1A (Continued)

3/4" Maximum

Cement	4.7 sacks/cu.yd.
Sand	40% by volume
Gravel	60% by volume
Air	4.0% by volume
Water	6.5% gal/sack

SITE 1B

1 1/2" Maximum

Cement	5.71 sacks/cu.yd.
Sand	31% by volume
Gravel	69% by volume
Air	4.0% by volume
Water	5.0 gal/sack

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3/4" Maximum

Cement	5.57 sacks/cu.yd.
Sand	36% by volume
Gravel	64% by volume
Air	4.0% by volume
Water	5.50 gal/sack

SITE 1C

1 1/2" Maximum

Cement	5.76 sacks/cu.yd.
Sand	30.5% by volume
Gravel	69.5% by volume
Air	4.0% by volume
Water	5.25 gal/sack

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3/4" Maximum

Cement	5.81 sacks/cu.yd.
Sand	38.5% by volume
Gravel	61.5% by volume
Air	4.0% by volume
Water	6.0 gal/sack

At each site a construction control laboratory was built for both soil and concrete work.

FORMS

At each site three types of forms were used. The conventional type forms were used for all structures with the exception of the Control Center and Power House domes and the Missile Silo walls up to 16 feet from top.

The conventional type forms were built in accordance with standard construction practices. Material used was 2" thick tongue and groove board with 3/8" thick plywood lining. (See Figures 36, 37, 38, 39, 40)

The forms for the Control Center and the Power House domes were movable steel forms. (See Figures 41, 42 and 43)

For each structure, there were two opposed orange peel forms 1/8 of the diameter of the structure, mounted on track and supported by structural members to center pivot post. (See Figures 42 and 43) Concrete placement was made simultaneously in each form, and forms were moved at same time. These forms first

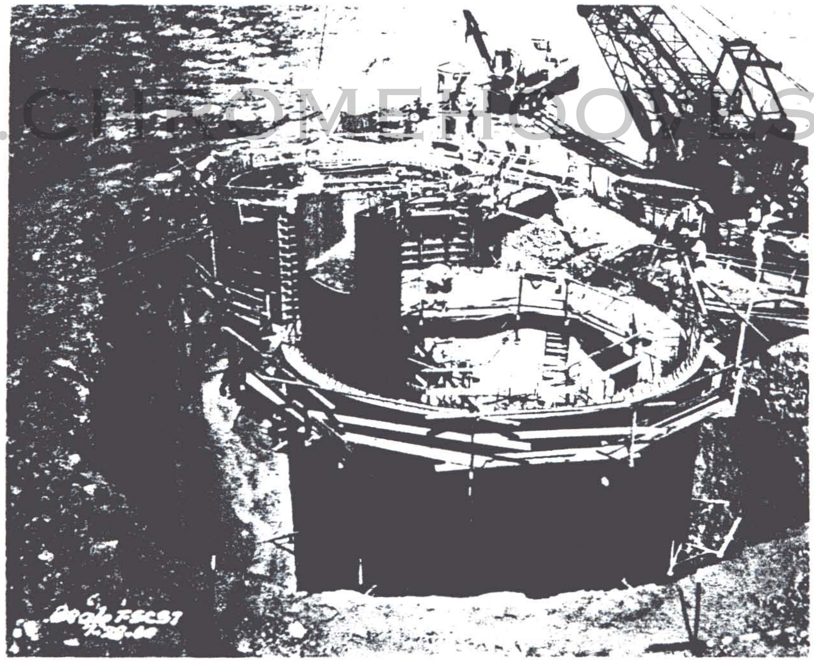

Fig. 36

Setting Forms, Antenna Silos, Site 1C

Fig. 37

Form Propellant Terminal, Site 1C

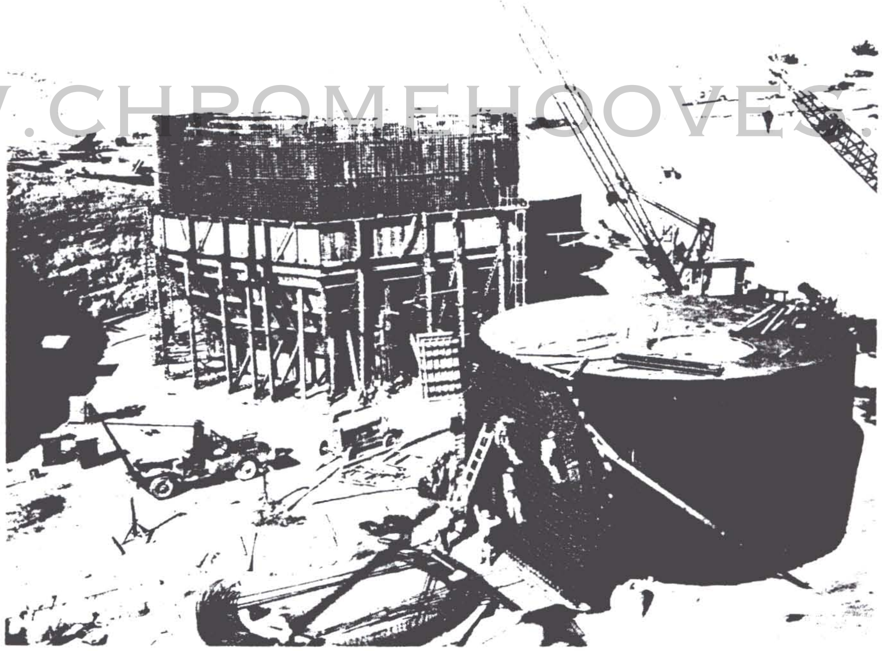

Fig. 38

Form Missile Silo #2, Site 1A

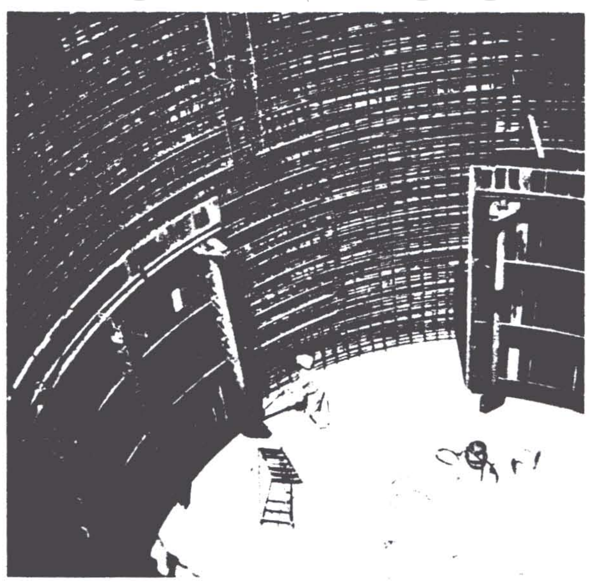

Fig. 39

Form, Site 1A, Equipment Terminal Wall

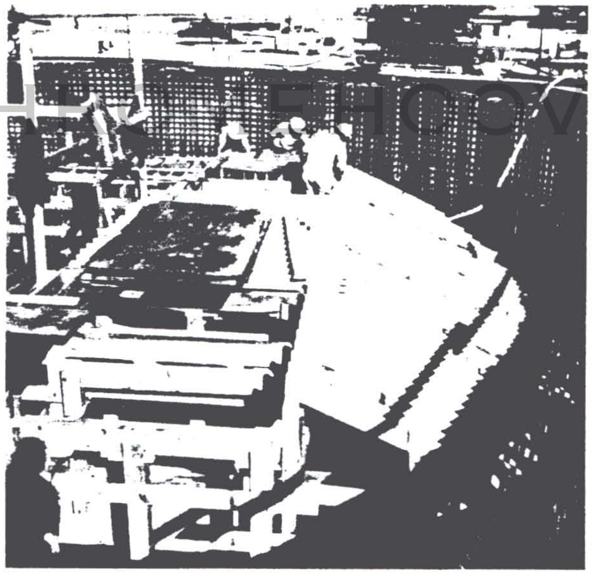

Fig. 40

Form, Site 1A, Missile Silo Top Slab

Fig. 41

Movable Steel Forms, Control Center, Site 1A

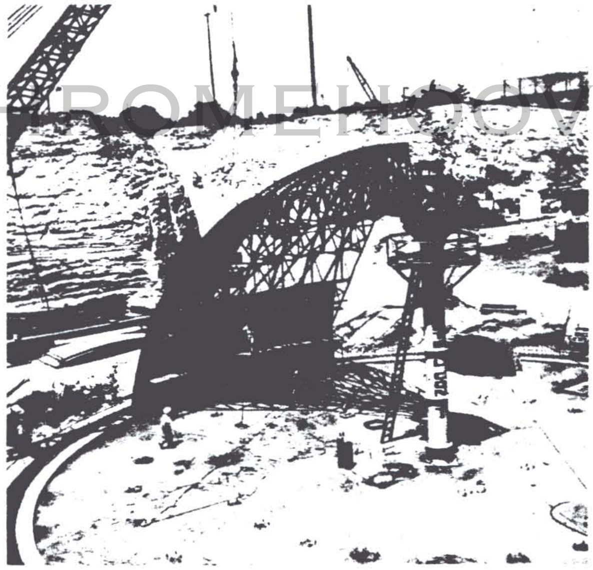

Fig. 42 ✓

Movable Steel Forms, Control Center, Site 1A

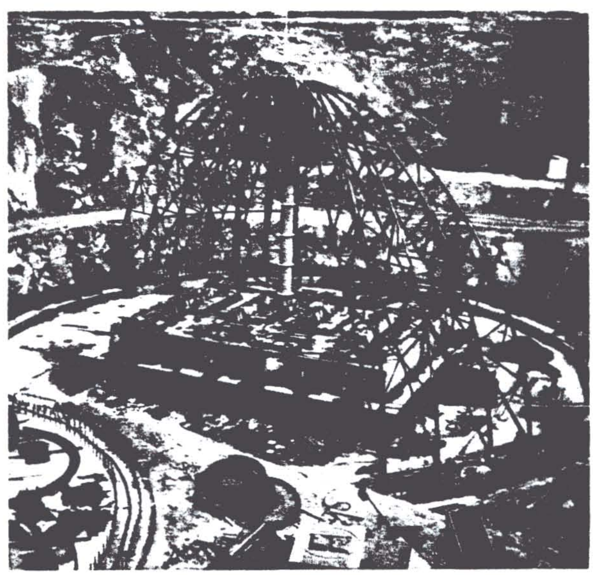

Fig. 43 ✓

Movable Steel Forms, Powerhouse, Site 1A were used at Site 1B, secondly at Site 1A and final use was at Site 1C. During the first placement at Site 1B it was discovered that an additional row of windows was needed near top of form. The spacing between the top row and the one below was too great to permit adequate vibrating. After this correction, only minor problems were encountered.

The slip forms used for the Missile Silo wall pours were the third type of forms used. As with the conventional forms, materials were 2" tongue and groove board and 3/8" plywood lining. The first slip form used at Site 1A had three platforms. (See Figures 44 and 45) The top platform was for material storage, and concrete hopper. (See Figure 46) The middle platform was working platform for concrete placement and the final work on embedded items. The bottom platform was for operating the hydraulic jacks and for the concrete finishers. After the first Missile Silo at Site 1A was slipped, the upper platform, except for the hopper, was discarded. Thirteen hydraulic jacks were used on the first slipping. Due to the additional strain imposed by the weight of concrete and hopper, two additional hydraulic jacks were added under the hopper for the remaining slipping. The hydraulic jacks were manually operated from a central control station. The overall length of the vertical face was six feet. The form was operated to keep it slightly higher than the freshly placed concrete. The slipping was continuous with an average rate of progress slightly over a foot an hour. During the slip form operations the greatest difficulty encountered was in controlling the roundness of the form. The roundness of the concrete wall was checked from four control wires, one at each quadrant intersection, stretched from point near top of silo to the bottom. In all silos the form became out of round, resulting in numerous embedded items, notably the unistruts, not being flush with the concrete. (See Figure 47) Additional cables were added across the forms and attempts made to force form back into position. However, out of roundness still occurred for all slipping. Contributing factors for this condition were the unequal expansion of the wooden platform due to moisture absorption and also the bulging of the steel reinforcement. (See Figure 48)

Slip forming at Site 1A and 1B was concurrent. Start of operations was on 26 August 1960 and completion on 29 October 1960. At Site 1C start was on 7 November 1960 and completion on 11 December 1960.

A form fabrication yard was established at Site 1A. Forms for the three sites were built at this yard and transported by truck to Sites 1B and 1C. Many of the forms were used from site to site.

STEEL REINFORCEMENT

The steel reinforcement work was done by Yuba Erectors of Emeryville, California.

Resteel sizes ranged from No. 5 through No. 18. The No. 18 bars were used in the Missile Silo top pours, in the Air Intake and Air Exhaust structures and Missile Silo Foundations at Silos 1B and 1C. (See Figure 49) Difficulty was encountered in placing concrete in many of the pours due to quantity of resteel

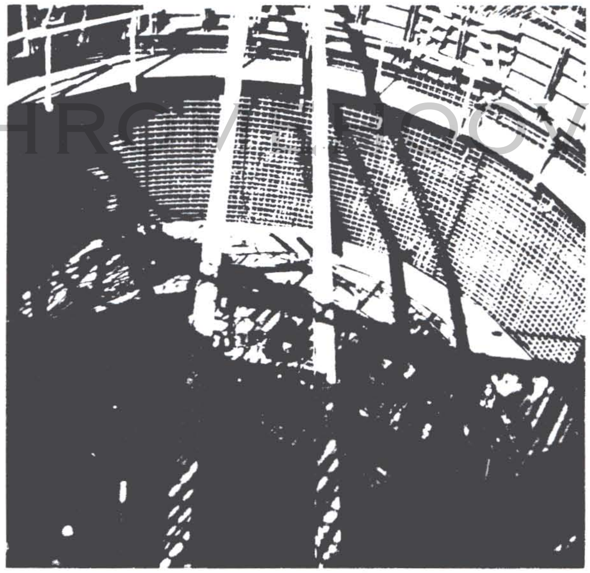

Fig. 44

Slip Form, Missile Silo #1, Site 1A

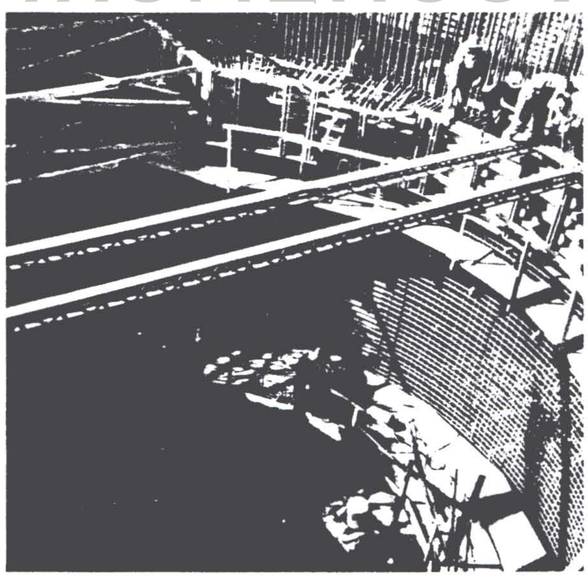

Fig. 45

Slip Form, Missile Silo #1, Site 1A

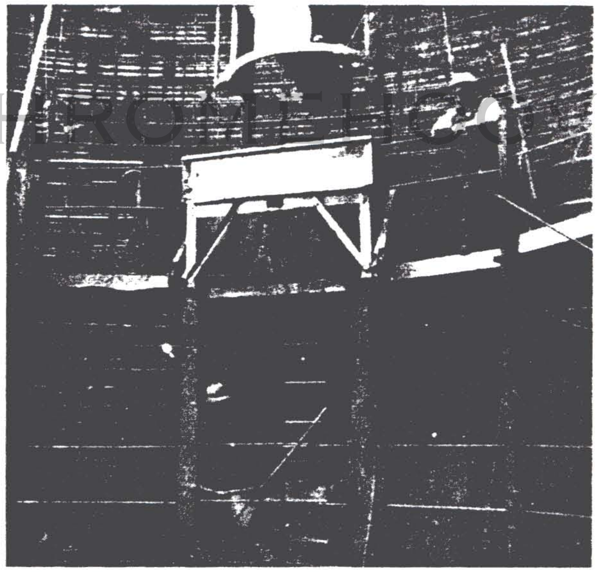

Fig. 46

Slip Form, Missile Silo #1, Site 1A
Buggie, Hopper and Hoist Bucket

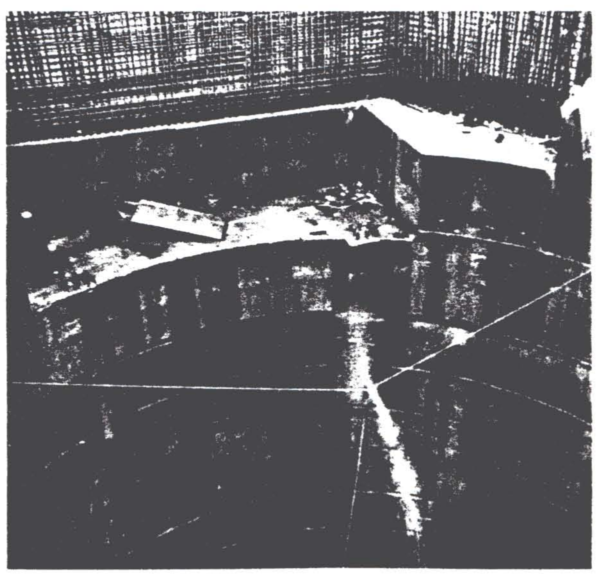

Fig. 47

Concrete Wall Finish Missile Silo #1, Site 1A

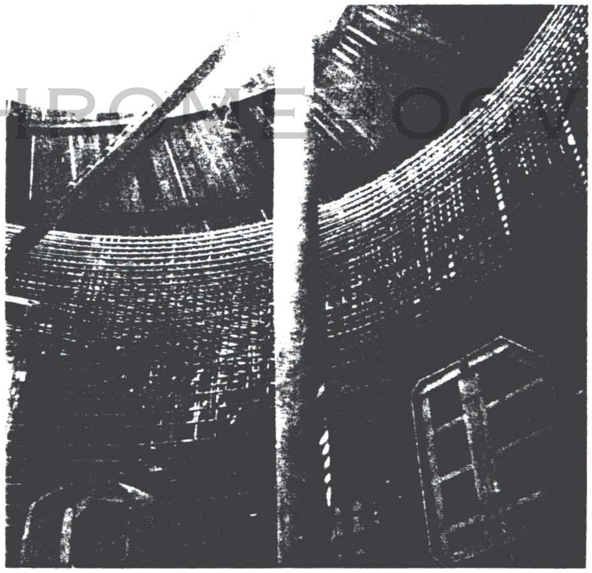

Fig. 48

Reinforcement Steel, Missile Silo #1, Site 1A
Also LOX and Heating and Ventilating Tunnel Openings

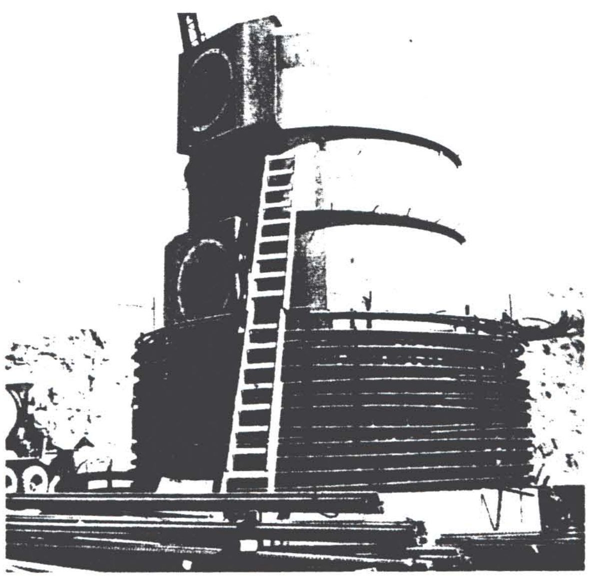

Fig. 49

Reinforcement Steel, Air Exhaust, Site 1A used.

Resteel was placed in accordance with normal construction practices. (See Figures 50, 51, 52, 53 and 54) For the placing of the wall resteel in Missile Silos, swinging platforms, one a single deck and the other with four decks, (See Figure 55) were used. These platforms were raised and lowered by crane.

The most serious problem encountered was bulging of the resteel in the Missile Silo walls during slip forming. Certain sections were forced back to allow clearance. Only minor problems were encountered in the placing of resteel for the other structures. In the Missile Silos and Equipment Terminals all reinforcing steel was bonded for electrical continuity by welding splices and a portion of intersection where layers of steel crossed at right angles. The steel walls were also connected electrically with grounding matting beneath each structure.

<u>CONCRETE PLACEMENT</u>

With the exception of the slip form operations and Power House foundation slab pours, cranes were utilized in placing concrete. (See Figures 57 and 58)

During the slip form operations, concrete was dumped from transit mix trucks into a chute. (See Figure 56) The chute dumped the concrete into a cubic yard bucket. This bucket was raised and lowered along guides by hoist, and dumped into a hopper above the work platform. From the hopper the concrete was dumped into hand buggies and placed where required.

In the placing of the Power House spring beam supported slabs, transit mix trucks dumped concrete into hoppers. From the hoppers the concrete was dumped into power buggies and dumped from them where needed. (See Figure 57)

Concrete vibrators were used in all concrete placement. One to three cranes were used. During placement of the Missile Silo tops, two to three cranes were used. Two cranes were used on the Control Center and Power House dome pours. Concrete buckets of $1\frac{1}{2}$ cubic yard capacity were used. (See Figure 58)

Ice was used during the hot weather to cool the concrete mixes below 80° F. The ice was added at the batch plant. At Site 1A the ice was crushed, weighed, dumped on conveyor and into truck from loading hopper. At Sites 1B and 1C, the ice was weighed, crushed and by means of blower, transmitted to the loading hopper into the truck mixer.

FINISHING AND CURING

The walls of the Missile Silo were form finished. Rough areas were smoothed with wood float and some areas required patching. A rainmaker was supported below the bottom platform by light cable. This rainmaker supplied full water coverage to the walls.

All unformed surfaces that were not to be covered by additional concrete or backfill had either a wood float finish or steel trowel surface. Floor slabs were steel trowel finished. Top slabs of Missile Silos, except for buttresses which were steel troweled, Entry Portal and Antenna Silos were wood float finished. Missile Silo, Antenna Silo and Entry Portal Doors were wood float finished. (See Figure 59)

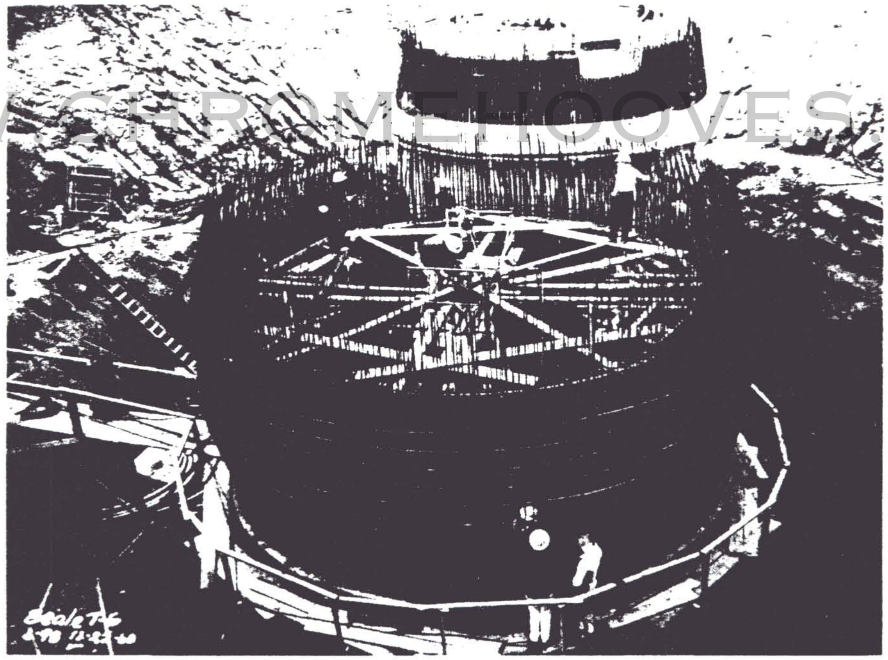

Fig. 50

Reinforcement Steel, Antenna Silos, Site 1A

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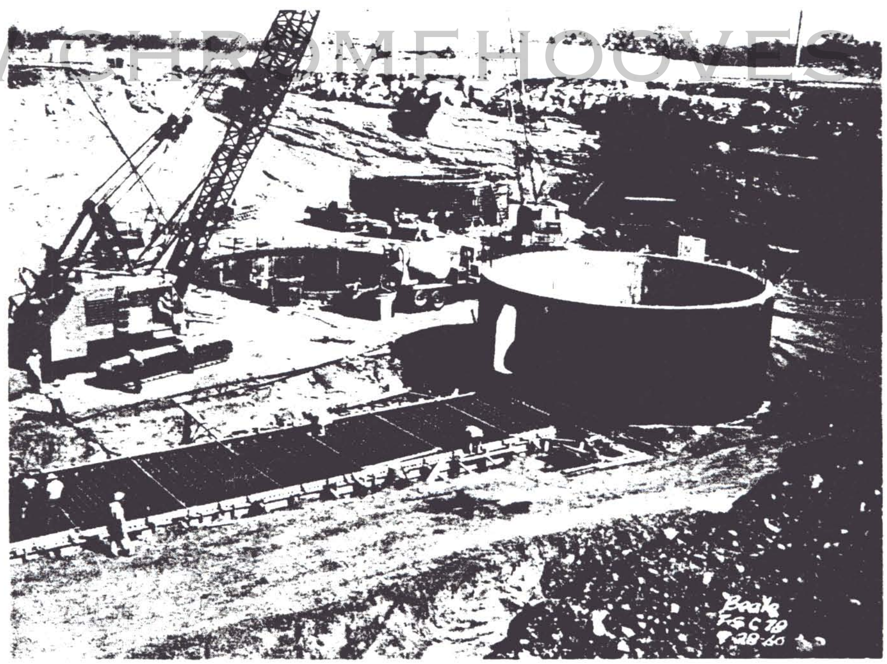

Fig. 51

Reinforcement Steel, Foundation for Liquid Oxygen Tank, Site 1C

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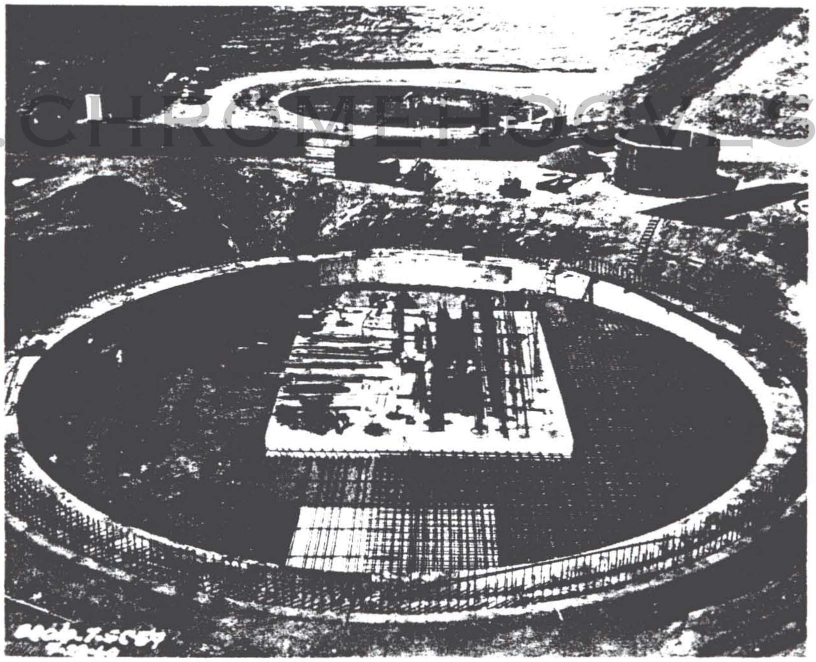

Fig. 52
Reinforcement Steel Foundation, Powerhouse, Site 1C

Fig. 53
Reinforcement Steel For Door, Missile Silo #1, Site 1A

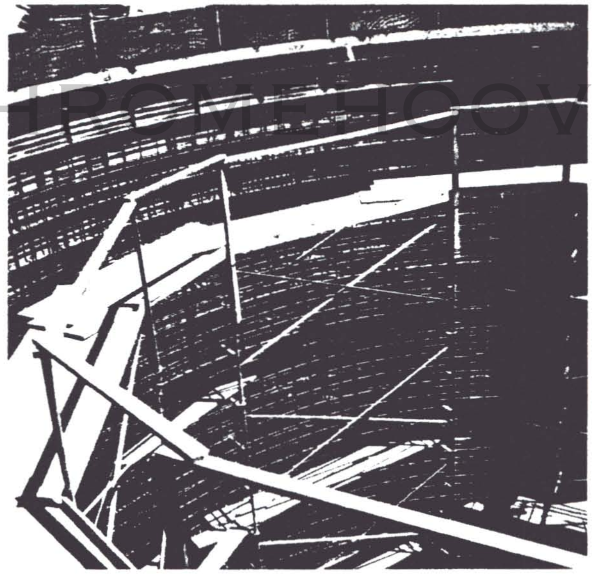

Fig. 54
Reinforcement Steel, Equipment Terminal, Site 1A

Fig. 55
Four Deck Scaffold, Steelworkers,
Missile Silo #2, Site 1A

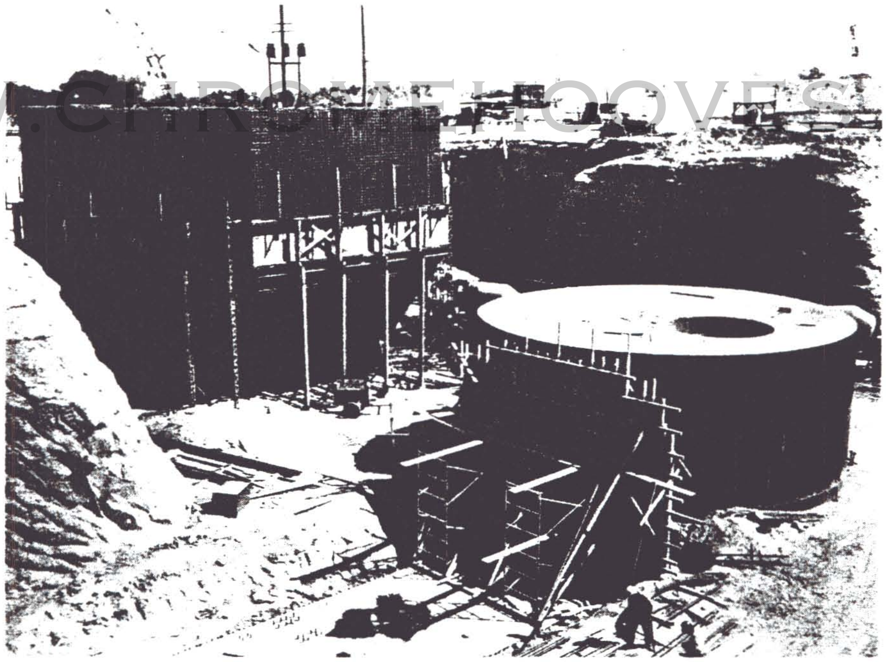

Fig. 56

Concrete Placement, Missile Silo #1, Site 1A

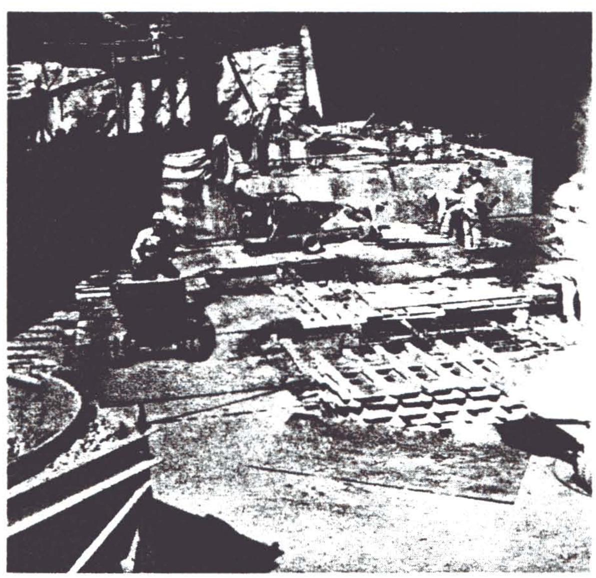

Fig. 57

Concrete Placement Showing Power Buggies,
Powerhouse, Site 1A

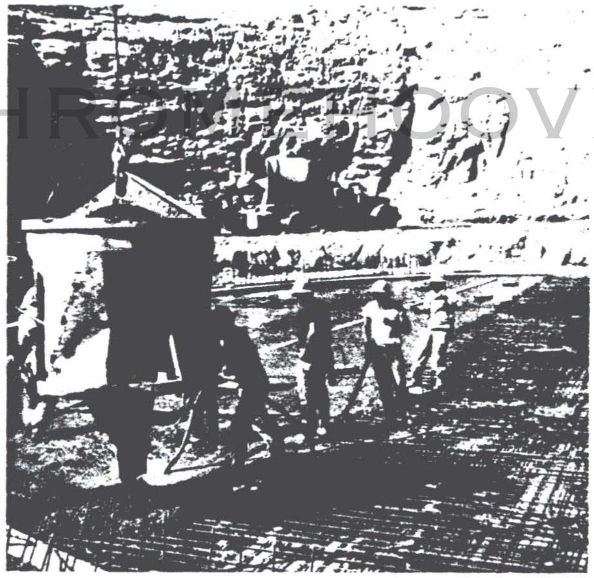

Fig. 58
Concrete Placement Showing Concrete Buckets, Site 1A
Control Center Foundation Slab

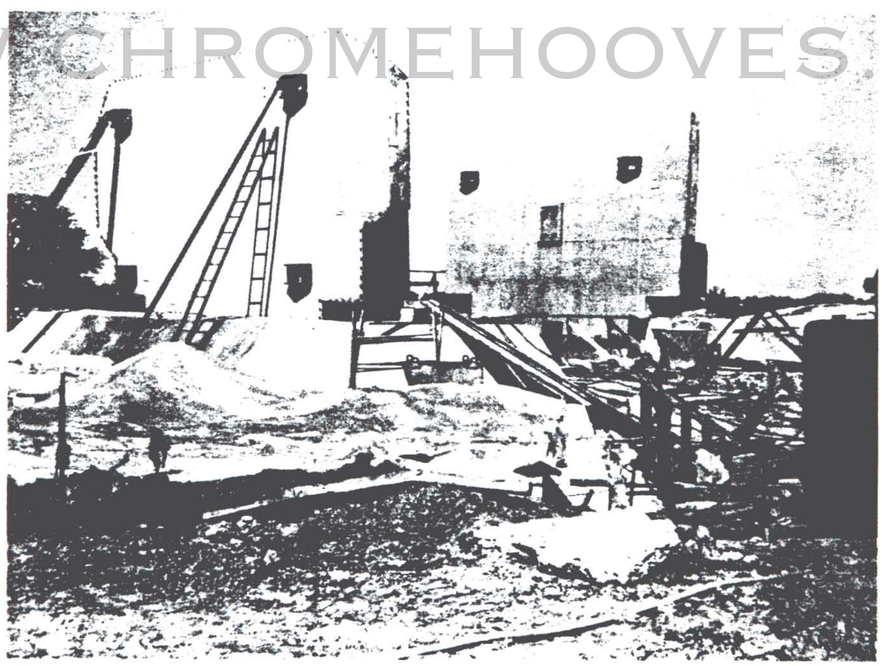

Fig. 59
Concrete Finish, Doors, Missile Silo #1, Site 1A

Curing was either water cure or with Edoco white pigmented curing compound. For those surfaces receiving waterproofing or dampproofing, the asphalt primer was used. (See Figure 60) Rainmakers or spray from perforated hose were utilized for water curing. Floor and foundation slab surfaces were flooded with water. Apparently the cure was effective as very little cracking of the concrete of any structure occurred.

DAMPPROOFING AND WATERPROOFING

Because of the seepage water conditions at Site 1A, all concrete structures were waterproofed. (See Figure 61) At Sites 1B and 1C the structures were dampproofed. The waterproofing and dampproofing operations proceeded exceptionally well and only minor problems were encountered. An asphalt primer was applied for both the dampproofing and the waterproofing. Two coats of hot asphalt were applied for the dampproofing. (See Figure 62) For waterproofing, five ply of thermoplastic bitumen treated fibrous glass membrane was applied with hot asphalt and protected on outside surfaces by fiber board. Inside foundation surfaces were protected by grout. Rock bolts were waterproofed with sealant.(See Figure 63)

MISCELLANEOUS

Ground Water

At Site 1A some trouble was experienced from the effects of seepage water during the placing of concrete and during the installation of some tunnels. The most serious trouble occurring during tunnel installation was that during the setting of Utility Tunnel #2, hydrostatic pressure raised the middle portion of the tunnel approximately 4 inches. No corrective action was taken and tunnel was left in this position. During the installation of the Antenna Terminal the seepage water had to be collected in a temporary sump and pumped out before terminal could be set. In the Missile Silos water from tunnel drains, and that leaking through concrete walls, seriously hampered progress of welders working on the structural and pipe work. A modification was issued to contractor to repair water leaks where necessary throughout structures. Repair work consisted either of sealing leaks with epoxy grout or by channeling the water to the nearest sump.

At Sites 1B and 1C no ground water problems were encountered.

Tanks

At each site three Liquid Oxygen Storage tanks were installed. These tanks were 56'6" in overall outer shell length, 11'6" in outside diameter and weighed 125,000 pounds empty. Each tank, for shock mounting, was suspended by hangers from a structural frame. This structural frame was supported from the foundation slab by steel columns. (See Figure 64) The tanks were protected by a rolled steel channel shell. (See Figure 65) Two 30 ton cranes were used in setting tanks. (See Figure 66) The tanks were shipped by railroad to nearest siding and then transported by truck to the sites. (See Figure 67) Tunnel excavation and installation were underway during this period which limited space available for truck and cranes.

One RP-1 fuel storage tank was installed at each site. These tanks were 43'0" in overall length, 11' 6 3/4" in outside

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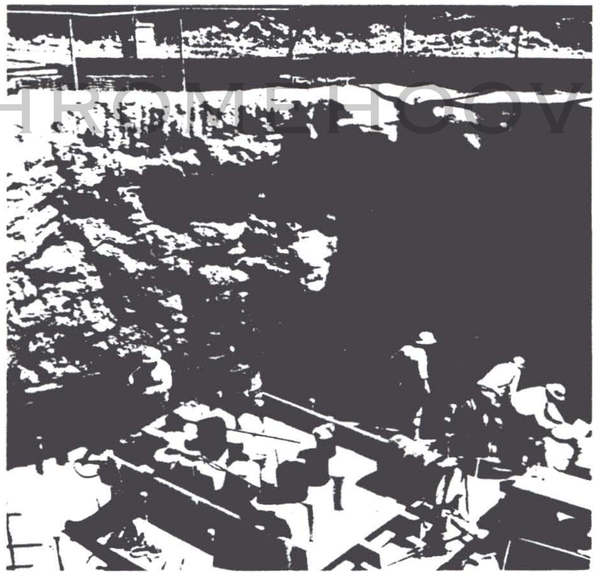

Fig. 61
Waterproofing, Site 1A, Propellant Terminal Footing

Fig. 62
Waterproofing, Site 1A

Fig. 63

Waterproofing, Rock Bolts, Site 1A

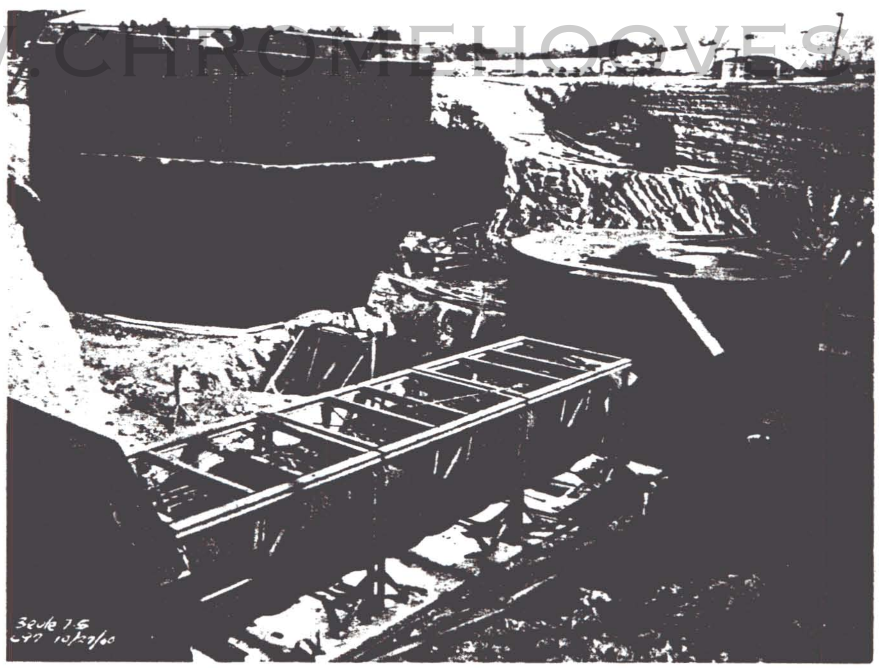

Fig. 64

Structural Frame, Liquid Oxygen Tank, Launcher #2, Site 1A

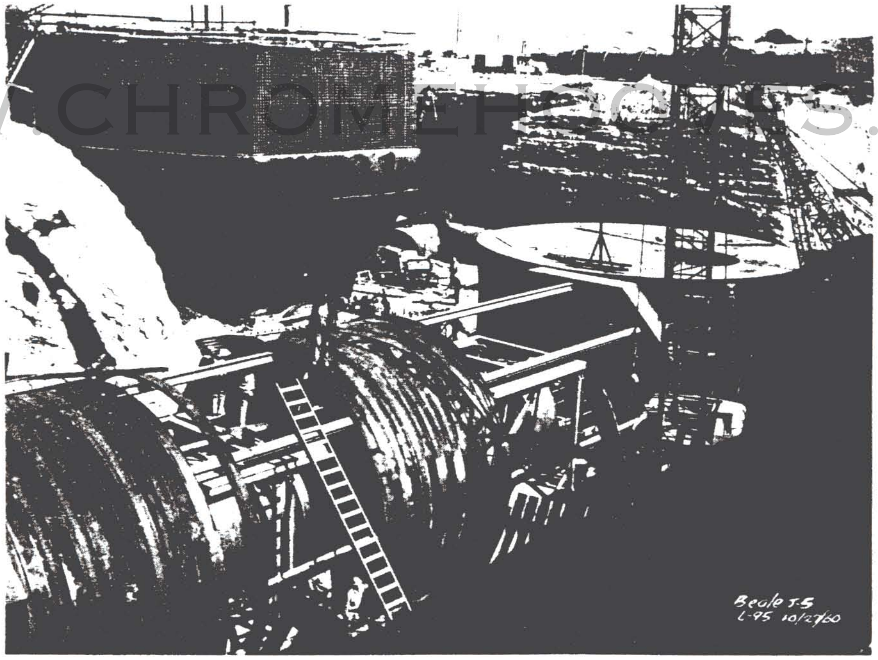

Fig. 65
Shell For Liquid Oxygen Tank, Launcher #1, Site 1A

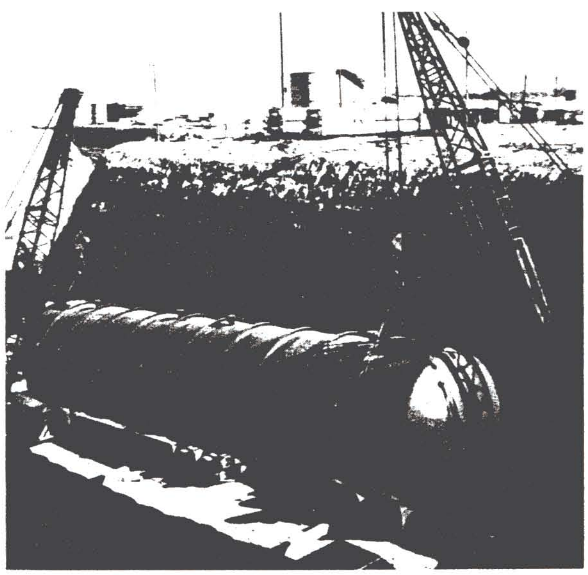

Fig. 66
Unloading Liquid Oxygen Tank, Site 1A

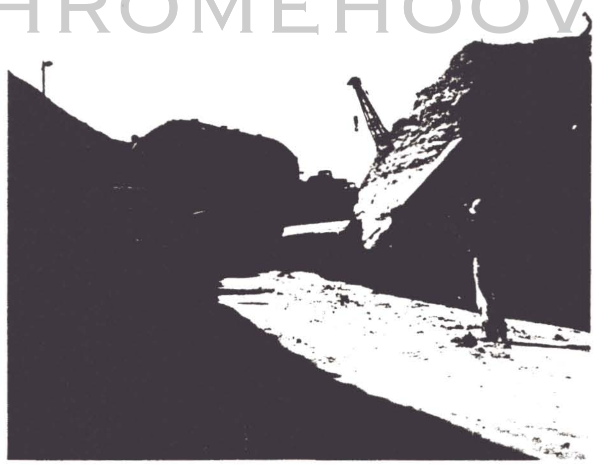

Fig. 67

Transporting Liquid Oxygen Tank, Site 1A

Fig. 68

Diesel Fuel Storage Tanks, Site 1B

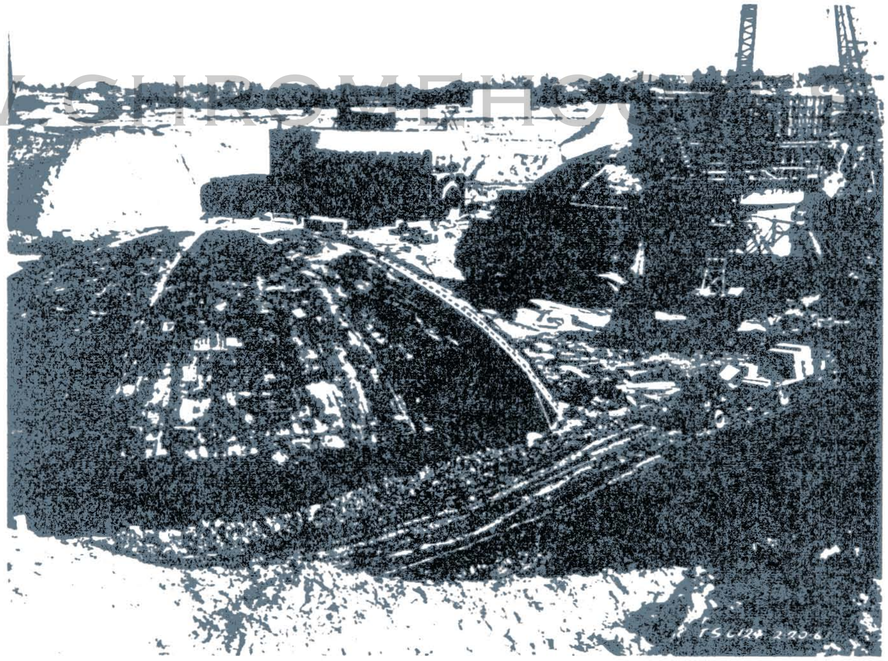

Fig. 60
Control Center, Powerhouse, Air Intake, Entry Portal
Showing Use of Asphalt Primer for Cure

Fig. 69

Personnel Tunnel, Site 1C

diameter and weighed 34,728 pounds empty. Before the setting of these tanks it was discovered that the angle ring at front end of tank was misfabricated and would not clear tunnel junction bulkhead. The bulkhead openings were reworked to allow clearance for tank. No other problems were encountered.

Only minor problems were encountered in the setting of the two water storage tanks at each site. The overall length of the tanks at Site A was 61' 0" and outside diameter 12' 0". The overall length of the tanks at Sites 1B and 1C was 38' 0" and the outside diameter 12' 0".

Three diesel fuel storage tanks were installed at each site. (See Figure 68) Two of the tanks were 80' 0" in overall length and 12' 0" in outside diameter. The third tank was 24' 0" in overall length and 6' 0" in outside diameter. No unusual problems were encountered during installation.

7. STEEL TUNNELS

The Armco Drainage and Metal Products Company installed the steel tunnels and tunnel junctions. The tunnel system consisted of personnel tunnels (See Figure 69), utility tunnels, PLS interconnecting tunnels, ventilation tunnels (See Figure 70), tunnel junctions (See Figure 71) and Antenna Terminal. Two reinforced concrete blast locks, not part of Armco's work, provided blast protection from each launcher. (See Figure 72) In the ventilating tunnel system an air filtration structure provided for the air supply. (See Figure 73)

Armco established two fabrication yards, one at the Lincoln Airport to supply Site 1A and the other yard at Chico Airport to supply Sites 1B and 1C. At these yards the tunnel sections were assembled. Herrick Iron Works of Hayward, California fabricated the tunnel junctions at their Hayward, California plant. Tunnel sections were transported to the sites by truck. Tunnel junctions were shipped by railroad to nearest rail siding and then by truck to site.

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The tunnel sections installed for the tunnel between Tunnel Junction 10 (Power House - Control Center) and the Antenna Terminal were preformed in the shop to a 3 percent larger vertical diameter. The tunnel section for remaining tunnels, with exception of the ventilating tunnel, were fabricated with ring beams, spaced 14 feet. (See Figures 74 and 75)

At Site 1A the installation of the steel tunnels started on 9 August 1960, at Site 1B on 15 September 1960 and at Site 1C on

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6 September 1960.

At Site 1A difficulty was experienced in connecting the tunnels to the tunnel junctions. At this site a 2 1/2" round neoprene gasket was specified between connection of tunnel and inside rolled channel at opening of tunnel junction. The neoprene gasket was finally discarded and in lieu a steel ring was welded from end of channel to tunnel. At sites 1B and 1C, the ring neoprene gasket was not specified, and connections were made without difficulty.

After backfilling, some settlement occurred. At Site 1A the Antenna Terminal, the Air Exhaust Tunnel Junctions and the Air Intake Tunnel settled approximately 5 inches. In addition, the Air Exhaust Tunnel Junction into the Power House and the Air Intake Tunnel at both ends flattened about 7 inches at top. The only corrective work was done in the Air Intake Tunnel. Additional supports and neoprene waterstops were added. At Site 1B the Antenna Terminal settled approximately 4 inches. Grout was flowed under this structure to stabilize settlement. At Site 1C, the Air Intake Tunnel settled approximately 5 inches. However, the flattening effect at top was not as severe as at Site 1A. Additional supports were installed. No repair of the neoprene seal was required.

Construction control records indicated that compaction requirement had been met under all structures that settled.

Fig. 70

Ventilation Tunnel, Site 1A

Fig. 71

Tunnel Junction #10, Site 1A

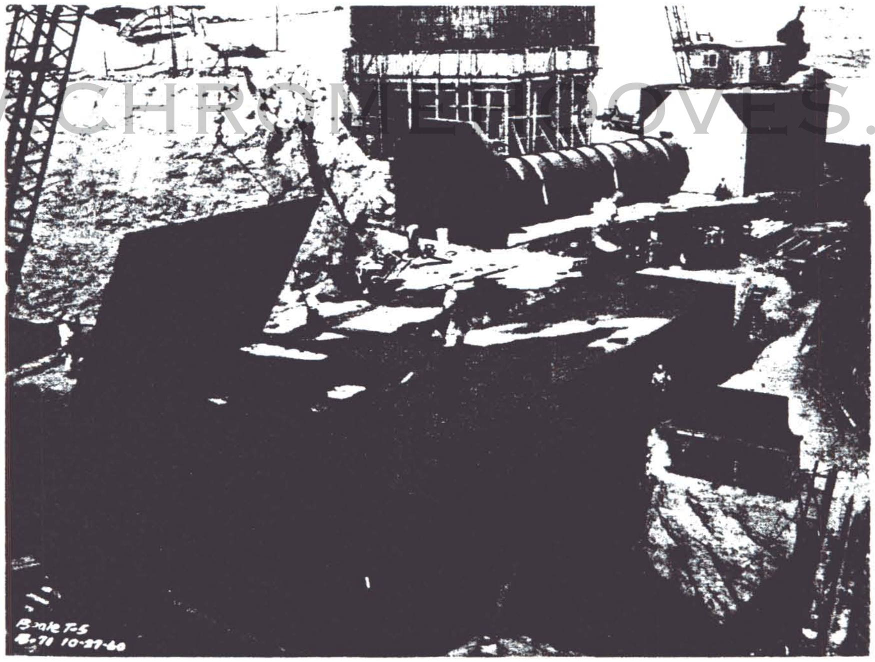

Fig. 72

Blast Lock #1, Site 1B

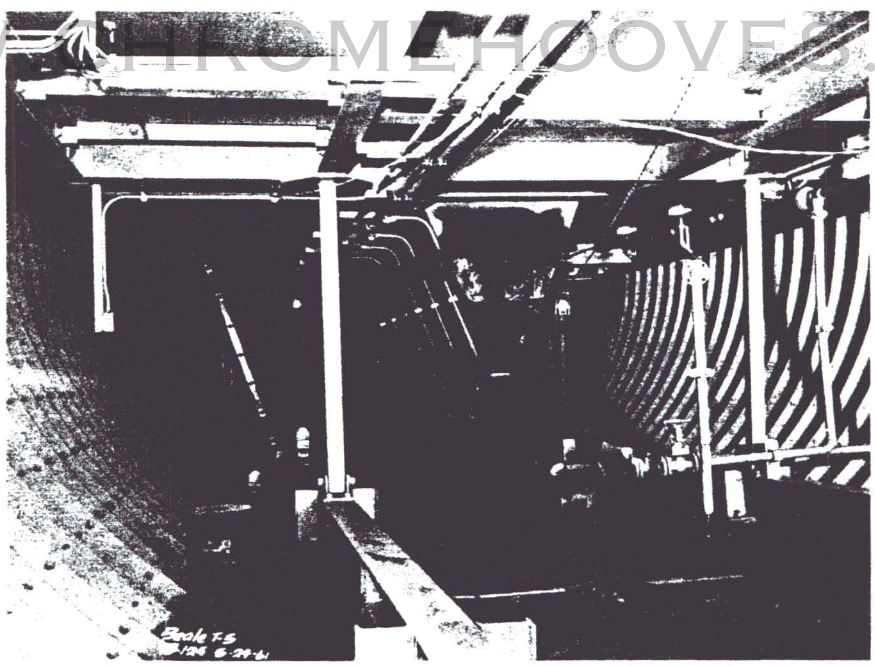

Fig. 73

Air Filtration Structure, Site 1B

Fig. 74
Steel Tunnel Section Showing Ring Beams, Site 1A

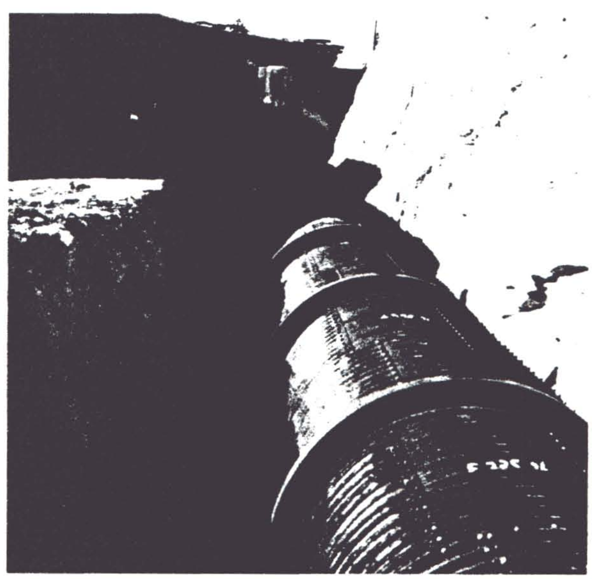

Fig. 75

Steel Tunnels Showing Rings, Site 1A
Blast Lock #2 to Tunnel Junction #2

8. STRUCTURAL STEEL

The structural steel was installed by the Keystone Fabricating Company of Compton, California.

In the Missile Silos all structural steel to elevation five feet was installed in the first sequence. This consisted of the pump platform and floor framing members. From this elevation and using the floor framing members as supports, a temporary working platform was erected. The inner columns of the working platform were constructed of six inch pipe and these were connected directly on the floor framing members. The outer portion of the working platform was attached to the wall unistrut around each level of the working platform. These levels of the platform were at twenty four foot intervals. The Lox and Fuel Cribs were installed in sections concurrently with the working platform. The tolerances of the crib-sections were 1/8 inch for outside dimensions and 1/4 inch for vertical alignment. (See Figure 76) 84 guide rail brackets for each Missile Silo were then installed on wall plates and these were set to a tolerance of 1/4 inch for elevation. (See Figure 76)

In the Power House a reinforced concrete main floor was supported from the pipe chase slab by reinforced concrete columns. The pipe chase slab was supported from the foundation slab by structural shock beams, designated as shock units "B". (See Figure 77) A reinforced concrete generator foundation slab was supported from the foundation slab by structural shock beams designated as shock units "A". (See Figure 78) The mezzanine floor consisted of checkered plate fastened to light and wide flanged beams. These beams were supported from the main floor by 8" I.D. standard pipe columns. An Austin Western Hydraulic crane was utilized in erecting the structural steel for the mezzanine floor.

The reinforced concrete floor of the first level of the Control Center was supported from the foundation slab by structural shock beams. (See Figure 79) The upper level floor was supported by wide flanged steel beams which were supported from the main floor by 10" I.D. pipe columns, extra strong. The outer portion of the upper floor was cantilevered. The Austin Western Hydraulic crane was used from the lower floor in erecting the structural steel.

The lower floor of the Propellant Terminal was supported from the foundation slab by 114 coil springs. (See Figure 80) The structural framing for the upper floor was supported from the lower floor by square and WF columns. Horizontal spring units were installed. These units were connected from the structural framing to wall plates embedded in the reinforced concrete wall.

The floor of Level I of the Equipment Terminal was supported from the foundation slab by structural spring beams. The structural framing for floors of the other three levels was suspended from structural spring beam cross members. The spring beams were welded to wall plates. The columns were connected to hangers by a pinned connection and the hangers to the underside of the spring

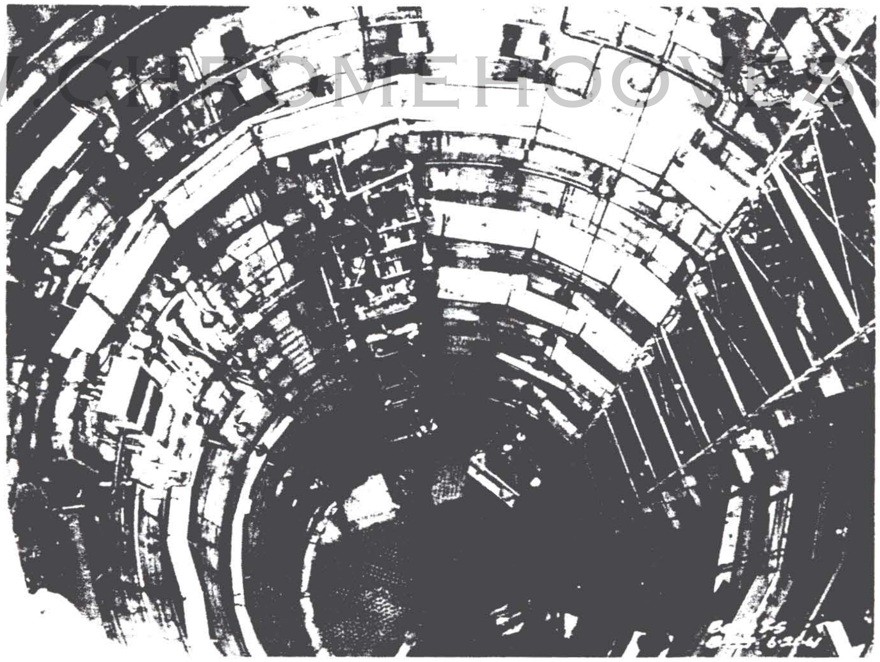

Fig. 76
Liquid Oxygen Fuel Crib, Missile Silo #1, Site 1B

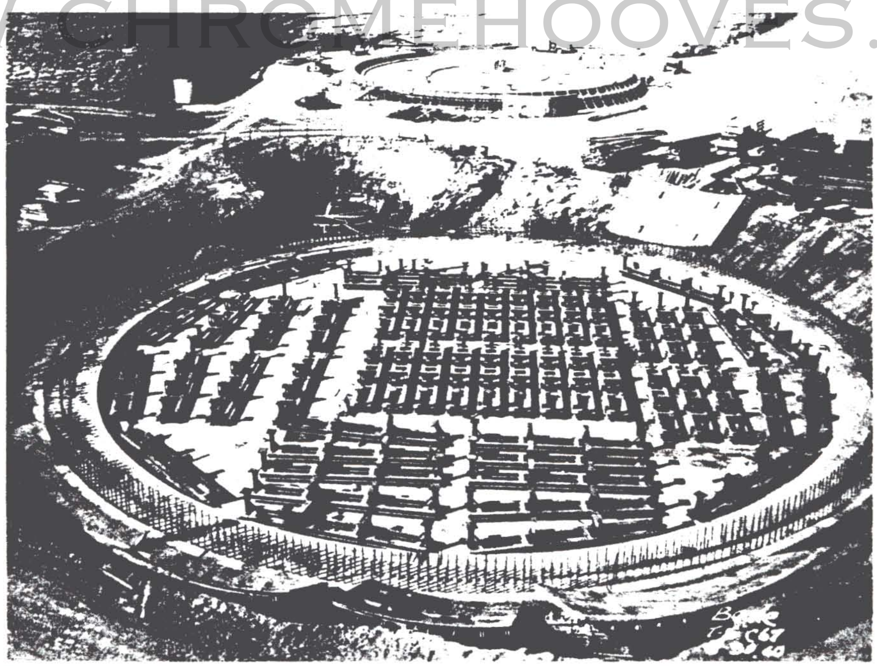

Fig. 77
Spring Beams, Powerhouse, Site 1C

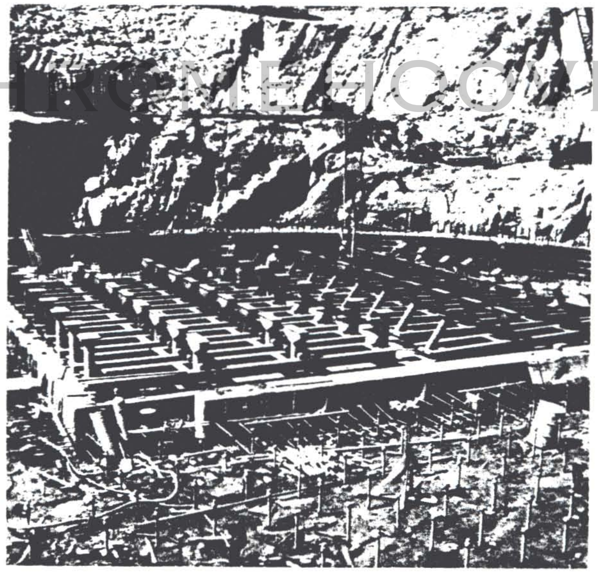

Fig. 78

Spring Beams, Powerhouse Generator Slab,
Powerhouse, Site 1A

Fig. 79

Spring Beams, Control Center, Site 1C

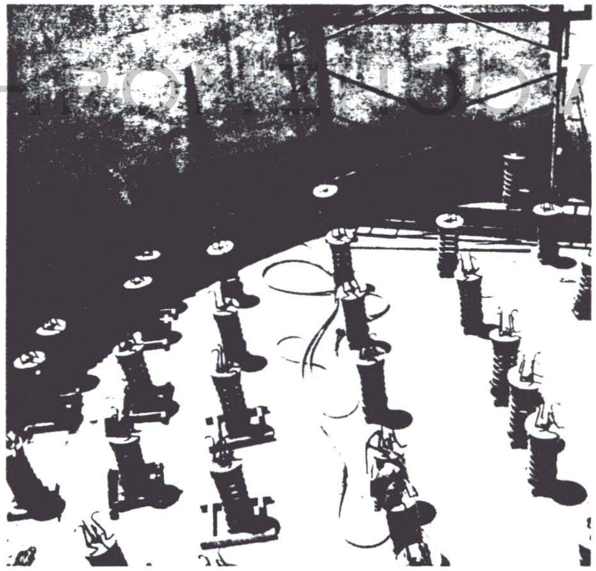

Fig. 80
Coil Spring Mounts, Propellant Terminal, Site 1A

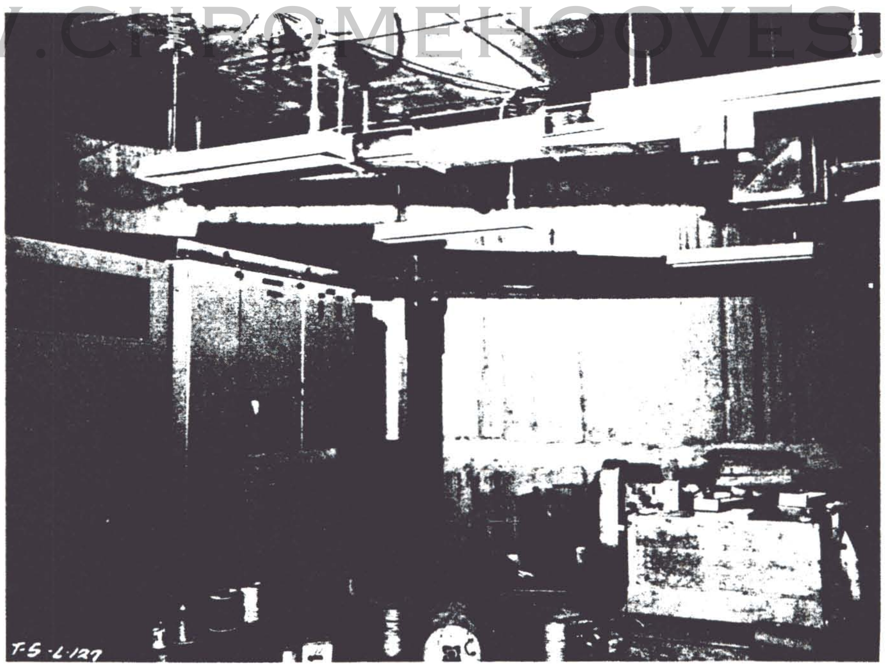

Fig. 81
Spring Beam, Equipment Terminal #1, Site 1A

beam by a pinned connection. (See Figure 81) The structural steel was erected prior to constructing the reinforced concrete roof.

The greatest difficulties encountered during the structural steel erection were setting the lox and fuel cribs in the Missile Silos to required tolerances and in reworking the structural shock beams in the Control Center. All cribs were reworked extensively before the tolerances were met. The pin connections of the shock mounts were found to be binding, requiring reaming of the pin holes to allow freedom of movement.

9. PROPELLANT LOADING SYSTEM

GENERAL

The purpose of the PLS was to store the missile propellants and auxiliary fluids and to transfer these fluids from the storage vessels to the missile. The system started at grade level with the storage vessel fill lines and terminated at the interface connections located in the missile silo. The propellants handled were liquid oxygen (-297°) and RP-1 fuel (high boiling point, aliphatic hydro-carbon). The auxiliary fluids were liquid nitrogen (-320°F), gaseous nitrogen and gaseous helium. A filtered compressed air supply was required for the actuation of the system's automatic control valves.

It was extremely important to keep this system clean at all times. The cleanliness requirements were far beyond those usually associated with the normal field construction requirements. The contamination limits were not to exceed the following:

1. Liquid oxygen, liquid nitrogen, gaseous nitrogen and gaseous helium systems:

   a. Total Hydrocarbons - 75 PPM(by weight as carbon)

   b. Acetylene - 1.0 PPM Illosvay method

   c. Total Solid Particles - 25 PPM(by weight)

   d. Particle Distribution - Maximum dimension in any one of three planes - 150 microns

2. RP-1 Fuel System

a. Total Solid Particles - 25 PPM(by weight)

b. Particle Distribution - Maximum dimension in any one of three planes- 150 microns

To assure that the piping and components met the stringent cleanliness requirements imposed upon the system, inspection techniques other than normal construction inspection were utilized. The following inspection methods were employed:

1. Visual - examination of all equipment for evidence of corrosion products, foreign matter and physical mechanical defects that constituted a reactive or functional hazard to the system. Optical devices such as angle mirrors, white light, lucite rods for directing light in a curved beam and boroscopes were used to examine normally inaccessible areas.

2. Black Lite - visual examination with the aid of an ultra-violet light source. Light source was a long wave (3660 angstrom units) utilizing a spot bulb to concentrate the light source upon the inspected area. This inspection was used to detect hydrocarbons, as most common hydrocarbons fluoresce under black light radiation.

3. Wipe Test - The area under examination was wiped, using a medium pressure, with a hard-surfaced, clean, filter paper. The paper was then examined under an optical comparator to determine particle size.

4. Millipore Method - During cleaning, a sample of the effluent of the cleaning media was passed through a millipore

filter pad. This pad was a specially constructed cellulosic porous membrane containing millions of capillary pores. The pad, after the media had been filtered through, was examined under an optical comparator to determine particle size of the contamination caught on the filter. This method of examination was used throughout and was particularly important on equipment that had inaccessible internal surfaces which could not be examined using visual and wipe test methods.

SYSTEM STORAGE VESSELS

The cryogenic and high pressure vessels and system sub-coolers were Government furnished equipment, supplied to the contractor for installation. The vessels were located in an underground area designated as the Propellant Terminal. They were filled or charged through lines that had their fill connections at grade level. All fluids prior to entry into the vessels were passed through a 40 micron filter located in the fill lines.

The storage vessels and sub-coolers were completely installed before the PLS piping was connected to them. Correct location of these units was therefore essential. The placement and locating of this equipment were accomplished without any extreme difficulties.

A problem arose in the contractor's acceptance of the Government furnished vessels. The construction contractor was reluctant to connect his clean PLS piping to the vessels without making a cleanliness examination of the vessels. Therefore, although accepted at the factory as meeting the standards for cleanliness, the contractor employed an independent laboratory to inspect the vessels. The blind flanges on the vessel connections were removed and the accessible areas given a visual, wipe and black lite inspection. Any contamination encountered was removed by cleaning the localized contaminated area with a suitable solvent, vacuuming, and/or brushing with a stainless steel or nylon brush.

After the areas were found acceptable, a blow down was made of the vessels. The vessels were charged with clean, dry, filtered GN_2 and a pad taken at the vessel's discharge connection. The GN_2 was blown to atmosphere through the blow down pad. When the analysis of the pad showed no particles over 150 microns and no hydrocarbons evidenced by black lite, the vessels were considered acceptable for connecting the PLS piping.

PLS PIPING

All piping was prefabricated and cleaned at a location centralized to the construction sites. The piping was fabricated into spool sections that could be easily joined by welding or bolt up in the field. After fabrication, the spool pieces were cleaned and then transported to the sites.

Due to the cryogenic temperatures, high pressures and shock loading requirements the liquid oxygen, nitrogen and gaseous oxygen, nitrogen, helium piping was fabricated from ASTM A-312, Type 304 stainless steel. The RP-1 pipe was fabricated from ASTM A-53 seamless carbon steel pipe. All shop and field welding was accomplished using a tungsten-inert-gas shielded arc welding process. To eliminate the use of backup rings, the pipe was purged with an inert gas during the welding operation. Argon was used as the inert gas.

The major problem encountered at the fabrication shop was carbide precipitation of the stainless steel pipe in the welded area. Although this condition did not adversely affect the physical strength at the weld area, it was difficult to clean the precipitated areas of the pipe. Exposure to the acid pickling solution attacked the precipitated area and produced a granular or sugared surface. Upon taking a wipe test of this area, it was impossible to find the filter paper free of particulate contamination. The condition of sugared welds was resolved by controlling the welding operations so the dwell time that the weld zone was subjected to the sensitizing temperature which produced the precipitation was kept at a minimum. Air cooling and water application between each weld pass were used as methods to control the time in the critical temperatures. Immersion time in the acid pickling agent was also controlled to keep exposure in the acid at the minimum time necessary to provide cleaning action. This reduced the corrosive attack upon the precipitated areas and did not leave the sand or sugared appearance in the weld areas.

The prefabricated spools were cleaned and sealed prior to shipment to the sites. Cleaning was accomplished by the following procedure:

1. Stainless Steel Pipe

    a. Mechanical descaling

    b. Degreasing (Vapor degreasing with Trichlorethylene)

    c. Acid Pickling (Solution of HNO_3 and HF)

    d. Demineralized Water Flush

    e. Drying (Hot, clean, filtered Air)

    f. Inspection

2. Carbon Steel Pipe

    a. Caustic Bath

    b. Mechanical Descaling

    c. Acid Pickling (Solution of HCL and inhibitor)

    d. Neutralizer

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    e. Rust Inhibitor Coating(Phosphate salt Solution)

    f. Dry (Hot clean filtered air)

    g. Inspection

After acceptance the open ends of the spools were sealed with a blind polyethylene gasket, taped, blind flanged and covered with a polyethylene bag. The spools were then transported to the construction sites by truck.

The problems encountered at the cleaning facility primarily dealt with quality control. The final inspection area had to be kept clean and free of fallout from the incoming air supply. No cleaning was to be performed in the final inspection area. A constant check of the acid strength, temperature and contamination level was made. Hourly determinations of specific gravity and

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temperature, and a daily titration analysis were used to determine when the acid tank should be drained and refilled. These precautions were an absolute requirement and it was only through the concentrated efforts of all concerned that this was achieved.

At the sites the spools were stored in the following manner to protect them from damage and contamination:

1. Polyethylene sheets were placed on the ground.

2. Wooden stringers of sufficient depth to prevent flanges of stainless steel pipe from touching the ground were placed on top of the polyethylene sheets.

3. The pipe was placed on the stringers. Several layers of pipe were placed one on top of the other, taking care to prevent damage to plain ends and sealed flanges.

4. The pipe was then completely covered with canvas tarpaulins.

The spools were bolted or welded together in their actual underground field location in the launcher area. Prior to the start of work, the work area was cleaned and a protective polyethylene tent placed over the work area. When the sealed ends o the spools were opened and inspected, a flow of clean, dry, filtered nitrogen gas was maintained within the pipe. The pipe sp was given a visual, black-lite, and wipe test examination prior field welding or bolt-up. If there was evidence of minor contam nation, limited field cleaning was performed. No major pipe recleaning was accomplished in the field. Pipe spools requir extensive recleaning were sent back to the cleaning plant for