13. ELECTRICAL CONSTRUCTION

General

MacDonald-Scott & Associates subcontracted the electrical construction portion of the contract to D. W. Close Company of Seattle, Washington. In addition, the electrical maintenance for all phases of construction including temporary power facilities was included in the work by The Close Company.

The Close Company, main contract office, was set-up in Ephrata, Washington with field offices at each site. This main office had full charge of expediting materials and construction drawings. The Close Company furnished all electrical construction materials with the exception of standardized electrical equipment furnished by the Government such as diesel-electric generators, the 2.4 KV switchgear, and the alarm panels.

At the peak of electrical installation the Contractor employed approximately 75 electricians at each complex to cover two shifts. As more areas became available for electrical installation, it was possible to maintain a satisfactory rate of progress by utilizing a larger day crew and a lesser number of men on a second shift.

There were a number of delaying factors during the electrical phase of the work. One of these was the late delivery of materials. The absence of approved shop drawings served to make inspection of work by Corps of Engineers' personnel extremely difficult. In some instances rework was necessary when the final approved shop drawings were delivered to the site. Changes were also initiated and made during the progress of construction. However, there were no instances of major work being torn out to accommodate these changes.

The advent of joint occupancy by the Associate Contractors created a relatively high turn-over rate of personnel. A number of electricians terminated and secured employment with the Associates due to the assurance of a longer period of employment and possible overtime.

Wiring Methods

All wiring is enclosed in galvanized zinc coated, rigid thickwall, rigid thinwall, or flexible conduit.

Flexible conduit is provided to separate each zone and all rattle spaces with sufficient loops to prevent distortion. All installations were made in accordance with the National Electrical Code except where deviations were permitted by the specifications. The Missile Silos are wired per National Electric, Class 1, Div. 2, Group 0. The lighting, alarm systems and detection systems are all explosion-proof to the extent that arc producing devices are explosion-proof, sealed off by means of a EYS and carry home with rigid conduit or non-explosion-proof fittings and J-boxes. All conduits entering a missile silo are sealed off at the blast wall and continue with rigid conduit. These units are not water tight and difficulty was encountered from moisture entering into the conduit systems in the missile silos.

Lighting fixtures in the control center, powerhouse, equipment terminals, propellant terminals, antenna silos, and antenna terminals are adequate, being mostly fluorescent, instant start, and shock mounted for correct zoning. Lighting is adequate in the tunnels but is poor in the blast locks and tunnel junctions. A partial correction would have been to lower the fixtures below the cable trays and piping. The fixture size could have been one size larger or more fixtures could have been provided. Tunnel Junction No. 12 is also deficient in lighting as are the RP-1 storage crib, LOX storage cribs and tunnels.

Convenience outlet receptacles in the structures seem to be adequate and are well-distributed.

Wire size, color coding, lug terminals and conduit size have been kept well within specified rate and demands.

Conduit bends were kept to a minimum and pull boxes were installed where needed, even if not shown on drawings.

Flexible leads to motors were installed as necessary.

14. COMPLEX ROADS

General

A system of paved service roads connecting the launchers and appurtenances and the access road to the complex from the adjoining County road were constructed under this contract. The roads generally followed the terrain features and drainage structures were provided. The gradients of the roads were designed to match the existing structures. A sliding gate with an electrical lock was installed to separate the access and complex roads.

The S&S Sand & Gravel Company, Ephrata, Washington was awarded a subcontract by MacDonald-Scott & Associates on 28 April 1961 for asphaltic concrete paving, bituminous prime coat, stabilized aggregate base course, and surface stabilization.

MC-1 cut-back prime coat asphalt and 85-100 paving grade asphalt were used for road paving operations. A total of 17,398 gallons of prime coat and 4,224.3 tons of bituminous surface course were utilized at the complexes. Paving portion was done by the W. Vail Company.

The embankment for the complex roads was accomplished by Murphy Brothers Construction Company of Spokane, Washington.

A concrete tractor crossing, 20' x 50', was placed across the access road at each complex to enable the landowner of adjoining property to cross over to adjacent fields without damaging the road paving.

Following is a summary of access and complex road construction at each complex:

Complex 1-A

The roads were cut in from 20 March to latter part of May 1961. Paving aggregate was crushed at Complex 1-B for use in hot-mix paving at all three sites. However, due to the breakdown of the hot-mix plant, the paving mix for Complex 1-A was obtained from McAthee & Heath plant at Moses Lake, Washington. The plant was

under inspection of the Larson Area Office laboratory personnel. Marshall tests taken of mixture at time of placement and after paving had been completed indicated that it met contract requirements. The 15' 0" road was difficult to place with the Barber-Greene pavers as cut-off plates had to be used, resulting in a somewhat uneven road which had to be trimmed. The roads were paved during the period 24-26 August 1961. A total of 1,464 tons of asphaltic paving material was used.

Complex 1-B

The subgrade for the access road was constructed in 1960 using material obtained from the ditch excavation. The excavation was made with scrapers and hauled, spread, and the material processed on the roadbed. A light lift of gravel was placed on the road to keep the road in service during the site construction stage. Final shaping of the road was accomplished in September 1961.

The base course aggregates were processed and blended on the site by S&S Sand & Gravel Company. The crusher and screening plant was set up outside the security fence near the rock waste area. The material processed was secured from the rock excavated during the open-cut and shaft excavation operations on the complex. The base course, together with the asphalt aggregate, was processed and blended from stockpiled material in the spoil area.

Close checks of the aggregate gradations were kept by the Corps of Engineers' field laboratory personnel from the belt of the plant and also from the stockpile after the material was hauled from the plant.

The base course was hauled to the road bed, placed in windrows, wet down, mixed and blended, and laid down. Specified lifts not exceeding 8 inches were permitted. The material was compacted with pneumatic-tired equipment to 95% compaction.

A central hot-mix plant and weigh scales were set up on the site for the asphalt paving operation. Bituminous asphalt was delivered from the railhead in Warden, Washington. Road priming operations started on 12 September 1961; asphalt paving, by Vail Company, started on 13 September 1961, and was completed on 22 September 1961.

Complex 1-C

The subgrade of the access road was constructed early in the contract and maintained up to the time it was paved. The complex roads were, in general, constructed in conjunction with or immediately after the completion of backfilling. Road fill and subgrade was done by Murphy Brothers Construction Company. The paving was done by L. W. Vail Company of Pasco, Washington. Paving aggregates, except hot mix, were produced from excavated basalt rock from the complex's stockpile by S&S Sand & Gravel Company. The hot mix was produced and hauled, hot, from the plant at Complex 1-B.

Placement of the base course started on 25 September 1961. Placement started at the junction of the access road and the county road. Paving progressed to the security gate past Missile Silos 1, 2, and 3 thence to the Entry Portal and then back to the junction with road "B". Base course material was hauled from the site stockpile and spread by 5 c.y. dump trucks. A blade processed and graded the base course material. Compaction was accomplished with a tandem spring roller and a rubber-tired roller. Some difficulty was experienced securing compaction. This was due to improper moisture content in the base course material at the time of rolling.

Placement of asphalt started 3 October 1961. The hot mix trucked from the hot-mix plant at Complex 1-B was spread with a Barber-Green paver; rolling was done by a two-wheel roller. Two trouble areas developed in the placement of the

hot mix. First, the widths of the roads and the spread width of the paver were frequently incompatible. This required over-width paving and then cutting to specified width. The second, and more serious, was the advent of weather unfavorable to paving. Some time was lost due to low temperatures. Paving was completed on 12 October 1961.

Improvement of County Roads

County roads serving all sites were improved to handle heavy traffic expeditiously through arrangements made by the Air Force with the U. S. Bureau of Public Roads. The latter agency, in turn, arranged for the required improvement through the appropriate State and County Road Commissions.

15. ON-BASE SUPPORT FACILITIES

General:

Support Facilities for the missile launching sites were also constructed under Area supervision for the U. S. Air Force. All facilities were completed and turned over on or before scheduled dates.

Facility	Cont. No.	Invitation	Award	Compl.	Amount
Re-Entry Facility L. Hopkins, Contractor	3599	11 Aug 60	9 Sep 60	2 Jun 61	$174,789.27
LOX Plant H. Halvorson, Contractor	3622	31 Aug 60	25 Oct 60	3 May 61	385,377.70
Missile Assembly Bldg. Quality Builders, Cont.	3624	25 Aug 60	1 Nov 60	16 Aug 61	492,000.00

Re-Entry Facilities

The Re-Entry Facilities were designed for the Air Force by Thomas O. Williams & Associates, College Place, Washington. The Contract DA-45-164-ENG-3559 was awarded to the Lewis Hopkins Company, Pasco, Washington, on 9 September 1960 with Notice to Proceed given for the basic amount of $172,517.00 with a final completion date established as 2 June 1961.

On 14 September 1960, the Contractor started construction of a temporary access road, parallel to the north security fence, to allow entrance to area of construction. This was a Security Area and temporary barbed wire fencing had to be constructed around the immediate construction area.

Modification of the existing Inert Spares Building (Item 2) started on 26 September 1960. This work consisting of washroom facilities, office space, water service to building, and sanitary sewer facilities was completed and accepted by the Base Engineers on 1 November 1960 as Partial No. 1.

Alterations to the existing Mounded Concrete Igloo (Item 3) started on 13 October 1960 and were complete and accepted by Base Civil Engineers on 5 December 1960 as Partial No. 2.

The Segregated Magazine (Item 1), a concrete storage structure, was started on 22 October 1960. It was completed on 5 April 1961 and was accepted by the Base Civil Engineer on a Beneficial Occupancy Agreement on that date.

Construction on the S&I Building (Item 4) started on 10 October 1960. This consisted of a concrete block and structural steel addition to the existing Re-Entry Building. This addition included: Office space, maintenance shop area, an operational bay with a 5-ton overhead crane, and a utility room.

Support items (5 through 20) which included a new water service; increased power supply; new septic tank and drain field; storm sewer; relocation of fuel oil supply tank; asphaltic concrete pavement and Portland Cement pavement were completed together with the S&I Building addition, and final acceptance made by Using Service on 13 April 1961. Correction of deficiencies, consisting of removal of temporary barbed wire fencing and replacing of permanent fencing at temporary gate locations was accomplished by 21 April 1961. This was well in advance of final completion date of 2 June 1961. A minimum number of field problems were encountered, each being settled amiably with Contractor's representative and generally at no cost to the Government.

Re-Entry Facilities - 2nd Phase

Purchase Order LAO-61-73 Contract was awarded the ADT Company of Spokane, Washington. This work consisted of additions to ADT alarm system. This work started on 23 May 1961 and was completed and accepted on 1 June 1961.

Liquid Oxygen Plant

The 25-Ton Liquid Oxygen Plant and Helium Unloading Facility was designed for the Air Force by Tuttle Engineering Co. of Arcadia, California.

The Contract DA-45-164-ENG-3622 was awarded to H. Halvorson of Spokane, Washington, on 25 October 1960 with Notice to Proceed given for the basic amount of $385,377.00.

The Contractor started construction on the Helium Unloading Facility (Item #1) 27 October 1960. This consisted of gravel-surfaced turn-around adjacent to the Larson AFB railroad siding, a mechanical connection for unloading from tank cars, and an overhead electrical distribution system and flood lighting. No difficulties were encountered and this Partial (#1) of the contract was completed on 31 January 1961, and was formally accepted by the Using Agency on 3 February 1961.

Construction on the LOX Plant Building (Item #2) together with the supporting utilities, water, sewer, and industrial waste started on 31 October 1960.

Initial work of excavation for the foundation footings, water service ditch and sanitary sewer ditch revealed unsuitable material in the LOX Building area. The Contractor was directed to overexcavate and backfill. A change order was later issued per contract requirements to cover this operation. Following the placement of all underground utilities, the area was backfilled and compacted, and the building foundation footings, foundation walls, and equipment pads were poured. The erection of structural steel, insulated metal walls and roof was accomplished on schedule with some minor field changes at no cost to the Government.

Construction of the concrete block end of the building, comprising office, storage, laboratory, and toilet facilities was accomplished during January 1961 with use of a heated Visqueen structure. The installation of plumbing, electrical heating, lighting and flood lighting, and ventilators was accomplished with no difficulty. The concrete floors were then poured, completing this Item 2 in March 1961.

Construction of the electrical distribution to the LOX Plant, Switching Station, and Substation, all under Item #3, was accomplished with no difficulties encountered. Relocation of some poles, addition of guys and guy poles at substation were necessary to make a workable job. This was accomplished at no cost to the Government. Upon request of the Grant County Public Utility District and with authorization by the SATAF, the original 6-pole switching station was revised to a single-pole switching station. This was accomplished by change order.

The LOX Plant Building, Item #2, and the Electrical Distribution, Item #3, were completed and were officially accepted by the Using Agency on 16 March 1961 as Partial #2.

Item #4 included the cryogenic vessels with LOX-N_2 transfer piping system, purge tank, PC concrete paving and loading area and appurtenances.

The fabrication of the LOX and N_2 storage vessels and purge tank was accomplished by Herrick L. Johnston Co. at their factory in Columbus, Ohio. Some difficulty was encountered in shipping due to size of vessels but not enough to cause more than minor delay.

The LOX-N_2 transfer piping was accomplished by Industrial Contractors, being fabricated at Idaho Falls, Idaho. Piping was shipped by truck and cleaned at the Dow Chemical Plant at Warden, Washington.

The setting of LOX and N_2 vessels, purge tank, and the final installation of the purge line, fill lines, and the LOX-N_2 transfer lines were accomplished by Industrial Contractors.

Final testing of all process piping was accomplished by 2 May 1961, and lines were insulated by 12 May 1961. Delay was encountered when it was decided by SATAF that liquid N_2 being produced by the new equipment installed in the LOX Building should be used as a testing media in lieu of gas from a commercial source.

It was found that the Air Products Corporation, which was under Air Force contract to operate the plant in its initial stage was not required by the Air Force contract to maintain the degree of cleanliness required for gas used under the Corps of Engineer construction contract. A delay occurred while the Air Force contract was modified and while lines and vessels were flushed to permit production of an acceptable product. A change order to the Corps contract had to be written for this time extension. Final inspection of this Item #4 was accomplished on 16 May 1961 and the work formally accepted by the Using Agency as Partial #3.

The fine grading of the LOX Plant site, asphaltic concrete pavement and stabilization (Item #5) were accomplished on 3 May 1961. Inspection on this Item #5 was accomplished along with Item #4 on 16 May 1961 and formally accepted by the Using Agency as part of Partial #3.

Deficiencies found at final inspection were corrected immediately. All contractor requirements were completed and a letter of acceptance to the contractor was written on 26 May 1961.

Guided Missile Assembly

The Combined Guided Missile Assembly and Technical Supply Facility was designed for the Air Force by Quinton Engineering, Ltd., Los Angeles, California. The Contract DA-45-164-ENG-3624 was awarded to Quality Builders, P.O. Box 1503, Tacoma, Washington, on 1 November 1960, and Notice to Proceed was given for the basic amount of $414,200. The facility to be located in Bay 4 of the Eight-Place Boeing Hangar on Larson AFB. The first load of materials arrived on 11 November 1960. Actual construction started 17 November 1960. On 18 November 1960, the Contractor started construction of access road to existing Boeing parking lot. This access road (Item 1.1), constructed of asphalt concrete, was completed and accepted by the Using Agency on 5 December 1960 as Partial No. 1.

The Missile Assembly Building, of frame construction, was in two sections with an assembly area between and a fenced supply area adjacent to the west side in the North end of Bay 4. One section was essentially office, conference, and classroom space while the other contained storage, maintenance shops, testing and cleaning areas. Heating and ventilating units, utility lines, and air ducts were carried overhead, supported by the ceiling joists. This overhead installation resulted in excessive damage to the ceilings by craftsmen and/or tools breaking through. As a result a change order was consummated to allow construction of a series of walkways, with access ladders, to minimize future damage.

Changes in location of equipment (furnished by others) in the precleaning area, authorized by Using Agency, necessitated changes to the industrial waste system.

Inadequate design of nitrogen system resulted in numerous change orders which resulted in increased costs and in slippage in contract completion date.

Upon request by the Using Agency, beneficial occupancy agreements were signed for certain individual rooms as they reached completion. The first of these (Communication Room) was turned over for use of Cook Electric (an Air Force Associate Contractor) on 27 March 1961. Additional rooms were turned over on 31 March 1961, 17 April 1961, 27 April 1961, and 12 July 1961. The entire structure was turned over at final inspection on 16 August 1961.

Change orders issued to correct design deficiencies of the Nitrogen System were carried as punch list items after 16 August 1961. These were completed and final testing was successfully completed on 20 November 1961.

16. CONSTRUCTION PROBLEMS

Tunnel Settlement:

One of the most critical features of site construction was the large amount of hand compaction of backfill required in the vicinity of structures and of the numerous embedded items such as tunnels and tanks. Many of these items were difficult to compact around and beneath. Close control of compaction operations in these critical areas was essential to insure that the specified density was attained. Attainment of satisfactory compaction required continuous inspection, frequent testing and close control of lift thicknesses.

A critical compaction area and one in which adequate compaction was difficult to obtain was the area under the neoprene joint connections between the tunnels and the structures. The difficulty was compounded by the fact that the specifications required that the flexible rubber connection be placed from the outside rather than from inside the tunnel. As a result, a space large enough for a man had to be provided below the tunnel invert at each juncture so that the neoprene seals could be fastened from the outside. Connections of tunnels to tunnel junctions are rigid. However, there are 31 flexible tunnel junctures at each Larson Complex to which the problem noted applied.

At the Titan I facilities "upstream" from Larson, a settlement and deformation problem had developed in the tunnels from the Powerhouse to the Air Intake and Air Exhaust Structures. To make allowance for anticipated consolidation in the foundation fill under the tunnel, the invert grade was set about 2 inches high. To relieve the deformation problem, the contractor agreed to provide lean mix concrete to fill the area under the

haunch of the tunnel to either side of the invert to a point on the launch about 10 to 12 inches above the invert. The thickness of the lean mix concrete varied from 0 to 1 inches where the invert of the tunnel laid on the grade and depending upon corrugation embedment, to a 10 to 12 inch maximum thickness under the haunch. A 2-1/2 to 3 bag mix was used for the purpose and would essentially result in two separate wedges to either side of the invert with little or no slab action, because of the low concrete strength.

Deviation from plan grade and elevation of tunnel sections became evident in December 1960 at Complexes 1-A and 1-B. Inspection of points of actual or potential settlement, principally at tunnel blast lock junctions, tunnel junctions, Equipment Terminal, Propellant Terminal and Missile Silo junctions were made at both complexes during January 1961. The results and corrective action taken were as follows:

Complex 1-A:

The inspection showed settlement at six locations. The areas of settlement were at the three junction points of both Blast Locks and were in the order of two (2) to three (3) inches. Settlement and/or deformation incurred two visible hair line cracks at the top of the concrete interface between the "D" tunnel and the LOX vent tunnel at Launcher Area No. 2.

To provide information as to the cause of settlement, a total of 20 inspection probe holes were cut in the tunnels at the invert points during the period 30 January through 13 February 1961. These probes were made at locations approximately 4 to 8 feet from point of tunnel connection with the concrete structures. Of the 20 probes made, 12 revealed voids between

the tunnel invert and underlying soil bearing grade in the order of 1-1/2" to 14-1/2" with an average void depth of 7". In all cases measurement was taken from the top of tunnel corrugation to underlying soil layer, thus including the depth of corrugation as void space. Linear extent of voids under the tunnels was a function of the methods used in making connections with the various concrete structures and tunnel junctions as previously mentioned. Examination of these voids by the Project Engineer disclosed the following:

(1) Approximately 3 feet north of Blast Lock No. 1, the void observed was 14" at the ceneter and extended laterally about 3 feet each side of the center line. A void running at least 5 feet longitudinally was observed.

(2) Approximately 3 feet south of Blast Lock No. 1, the void observed was 8-1/2" at the center and extended laterally about 2 feet each side of the center line and longitudinally 3 to 5 feet.

(3) Approximately 3 feet east of Blast Lock No. 1, the void observed was 3" on the south side of the tunnel. No void was observed on the north side of the center line.

(4) Approximately 3 feet south of Blast Lock No. 2, a 5-1/2" void was measured.

(5) Approximately 3 feet north of Blast Lock No. 2 a 10" void was measured.

(6) Approximately 3 feet west of Blast Lock No. 2 a 5-1/2" void was measured.

(7) Section XX-3 taken 5 feet from P.T. No. 3 - 3-1/2" void.

(8) Section E taken center of section - 4-1/2" void.

(9) Section W10X taken 3 feet from M.S. No. 1 - 2" void.

(10) Section Y9X taken 3 feet from M.S. No. 3 - 1-1/2" void.

As a result of this investigation, the contractor was directed by Larson Area Office Serial Letter No. 1838, dated 17 February 1961, to fill all void areas beneath tunnel inverts and to install a second neoprene flexible joint on the connections to Blast Locks. Serial Letter No. 2761, Larson Area Office, dated 13 June 1961, waived the requirement for an additional waterstop between Blast Lock No. 1 and Tunnel Section Y-1. Grouting was completed under all tunnel sections with voids by 15 April 1961. A total of 5 cu. yds. of 5-sack mix was used. Periodic surveys and visual inspections have been made since that time. The results of these surveys have shown that no further settlement of tunnel sections has occurred.

Complex 1-B:

Inspection of tunnel settlement was made in January and February 1961. A profile survey showed that the tunnels had settled from 0 to 3½ inches with the average being less than 2 inches. Study of the profile indicated a general settlement throughout the length and a greater amount of settlement at the connections with concrete structures. A total of twenty-seven inspection holes were cut in the tunnel inverts. Eleven of the inspection holes showed a void under the tunnel. The void depth ranged from ½ inch to 9 inches with an average of 5 inches. Depth of voids was measured from the top of the corrugation on the inner side of the tunnel. In four of the inspection locations, Class "C" concrete had previously been placed

under the ring beam outside of the tunnel section and no settlement had occurred. Density of the material under the tunnels at six inspection openings ranged from 67.9% to 84.7% of modified AASHO. Flexible joint material ruptured at the concrete to the east end of Blast Lock No. 1 and the connections of the Personnel Tunnel to Missile Silo No. 2 and the Utility Tunnel to E. T. No. 3.

There was no evidence of tunnel deformation at the connection of tunnels with rigid structures. Deformation occurred within tunnel junction No. 8 where floor support members bent an estimated 2 inches. At the concrete wall of the connection of the LOX tunnel to the LOX vent in Launcher Area No. 3, damage occurred due to settlement and/or deformation. Bolts connecting the metal tunnel to the concrete wall, and bolts connecting metal channel sections sheared in several locations and concrete spalled. Hairline tension cracks appeared in the concrete. At the same point in Launcher Area No. 2, concrete spalled and hairline cracks appeared. However, bolts did not shear.

A review of the tunnel settlement problem at Complex 1-B and a proposed method of corrective action wasforwarded to SATAF on 31 March 1961. The suggested corrective work involving grouting to prevent further settlement was accepted by the Air Force with minor refinements by 4th Indorsement, subject: "Settlement of Tunnels, Complex 1-B, Contract No. DA-45-164-ENG-3552" Larson Area, dated 15 May 1961.

Grouting operations to fill the voids under the tunnel sections at Complex 1-B were performed by MacDonald-Scott & Associates during the period 14-30 June 1961. A total of 44,500 lbs. cement and 4,000 lbs. sand were used

In the grouting operation at Complex 1-B. Specific locations and quantities of grout under these tunnel sections are listed in Larson Area Office letter to SATAF, dated 3 January 1962, subject: "Tunnel Settlement, Contract No. DA-45-164-ENG-3552," Serial Letter No. 868 (.29).

Complex 1-C:

Settlement of tunnel sections at Complex 1-C was negligible. This was due to several factors, namely:

(1) Contract Specifications required the contractor at Complex 1-C to set all tunnel junctions on concrete. This was due to the water-proofing of tunnels from anticipated ground water.

(2) From his experience at Complexes 1-A and 1-B, the contractor voluntarily used a lean concrete bedding under all tunnel sections at the connection to rigid structures as well as under T. J. No. 10 and T. J. No. 12.

Based on the above no settlement of tunnel sections occurred or is anticipated at Complex 1-C.

Periodic surveys taken since grouting operations showed no further settlement of tunnel sections at Complexes 1-A and 1-B.

Rigging Failures:

Complex 1-A:

The doors of the East Antenna Silo at Complex 1-A were damaged as a result of the west door striking the east or lower door when it was dropped on 17 March 1961. The upper door was dropped during the opening procedure. The accident took place as the Caterpillar tractor was exerting tension on the horizontal cable and at the same time two cranes endeavored to keep the vertical cables taut. However, the 5/8" cable attached to the

tractor parted, imposing an impact load on the two cranes and the eye bolts to which they were rigged. The eye bolt to which one of the cranes was rigged then failed, and the entire load was transferred to the other crane. The weight of the door was too much for the second crane, and it closed, pulling the crane's back wheels off the ground without upsetting it.

The accident resulted in spalled and ravelled surfaces of both doors. The contractor used epoxy resin to perform repairs which were entirely satisfactory to the Using Agency.

Complex 1-B:

The West door of the West Antenna Silo at Complex 1-B was damaged while being lifted to the open position. The incident occurred on 27 March 1961 when the concrete was approximately 25 days old. Failure of the lifting eye bolts in the rig attached to the door occurred when an angle of 65-75^{o} from horizontal was reached using 2 portable cranes. Bolts, already weakened by welding to a beam-type lifting rig, were subjected to over-stress developed by horizontal force from pull line attached to Caterpillar tractor.

The door fell in an arc traversing approximately 14 feet impacting first on the receiving lip of the east door and followed by a second impact on the side concrete lips. Consequently, the door was subjected to bending in two directions with the most severe action occurring on first impact.

An initial crack survey, conducted when doors were raised to the vertical position on 5 April 1961, revealed three hairline cracks on the top surface of the door, 3 to 5 feet in length, perpendicular to the rotation pin or hinge and a complete crack through the lip overhang.

The following repairs were considered:

a. Remove lip and 2 feet of concrete beyond. Rebuild and add reinforcing steel and repour removed concrete.

b. Pressure-grout cracks with epoxy.

Both methods were considered inadequate when applied to revised scope of damage. Method "A" would require removal of 85% of the door. Method "B" could not be applied to all cracks. Consequently, restoring continuity and integrity of concrete was not attainable. In addition, the percent of cracking per unit area approached shattered slab proportions.

The contractor was directed to remove the damaged door and to replace it with a new door that satisfied specification requirements.

The door was recast in place (30 c.y.) and was successfully opened on 27 June 1961.

In addition to the door damage, additional investigation showed that the walls of the Antenna Silo were also damaged. The spalled and cracked concrete was chipped out and patched with an epoxy resin grout. An analysis of repairs indicates that the full design strength of the structure has been restored.

Water Seepage - Complex 1-C:

Selection of sites for Launching Facility Construction at Larson was made by an Air Force and DMJM&A Site Selection Team. At the time the location for Complex 1-C was designated the Bureau of Reclamation and the Corps of Engineers called to the attention of the Air Force the fact that the site was to be part of an irrigated area, with a probably eventual water table reaching to ground level. As a result, underground structures

were designed in consideration of such conditions and were constructed in accordance with the design.

Irrigation of the surrounding areas of the complex initially commenced in the middle of April 1961. Leakage of water into the facilities was first observed in Utility Tunnel No. 2 at the northern extremity of the Complex on 27 June 1961. This leakage gradually spread through Launcher Area No. 2, to Launcher Area No. 3 and then to Launcher Area No. 1 on 4 August 1961. This progression continued to Tunnel Junctions 12 and 10 and on to the Antenna Silo area. Initially on 28 July 1961, water was pumped from the facilities at the rate of 10,000 gallons per day. By the later part of August 1961 this quantity increased to a peak of approximately 175,000 gallons per day. The leaks were observed to vary from a jet stream to seep type. Localized repair by welding was directed by the Area Engineer. On 21 August 1961, the neoprene seals at Equipment Terminal No. 2 and Utility Tunnel No. 2 ruptured and detrital material entered the tunnels along with a water flow of several gpm. Temporary repair was made by placing a 1/8" neoprene patch over the ruptured areas (the patch was held in place by a steel backing plate with 2 X 2 angle iron stringer braces that were welded to the tunnel shell). The leakage rate diminished to an average of 9,700 gallons per day in December 1961 to an average of 3,000 gallons per day in March 1962. This reduction is due primarily to the seal welding of tunnel seams and bolts. Although irrigation of the surrounding areas stopped on 22 October 1961; eliminating the source of new water, the water table has remained at a level higher than the structures as indicated by pressure gages installed throughout the complex. The water reached its

highest recorded level at an elevation of 1183.64' on 27 October 1961. Elevation of the water table 14 March 1962 was 1172.25'.

Hydrological investigations began 2 August 1961. A backhoe ditched inside of the Security Fence on all sides except several hundred lineal feet in the SE corner of the complex where surface installations and buried water and electrical lines precluded ditching. It was anticipated if water entered the site at the surface, Palouse silty sand and upper Ringold caliche contact, an impervious-lined interceptor ditch could be constructed to prevent or minimize the volume of water gaining access to the structures. The ditch was excavated to a depth of 8 feet, penetrating an average of two feet into the caliche, but no free ground water was found.

In quest of deeper subsurface information, an auger drill which was adapted for limited rock drilling was contracted from Nichols and Thompson Core Drilling Company, Inc., Boise, Idaho. During the period 8-23 August 1961, an exploratory drilling program was conducted as follows:

a. Between the ground surface, through the Palouse and Ringold formation, terminating at the top of basalt rock, averaging between 20 and 25 feet; 33 holes were drilled on 100-foot centers around the complex in undisturbed ground outside of the open-cut slopes. Rock-bit holes were 4 inches in diameter.

b. Below the Ringold caliche, penetrating the top flow of the Yakima basalt formation, generally bottoming in hard columnar, relatively impervious basalt; 16 holes were drilled encountering ground water and deliniating the present flow and its horizontal extent around the complex.

c. Five auger holes were drilled through backfilled sections of the

complex. One was located opposite each Utility Tunnel where water was encountered initially, and the others were drilled in backfilled ramps. Auger holes were 8 inches in diameter.

No free water was encountered above the basalt. Water at an elevation of 1181 feet was found in drill holes in the backfill about 27 feet north of Utility Tunnel No. 2. In contrast, a drill hole northwest of Launcher No. 2 in undisturbed strata, revealed the top of water column at elevation 1183, the highest elevation of water encountered at the complex.

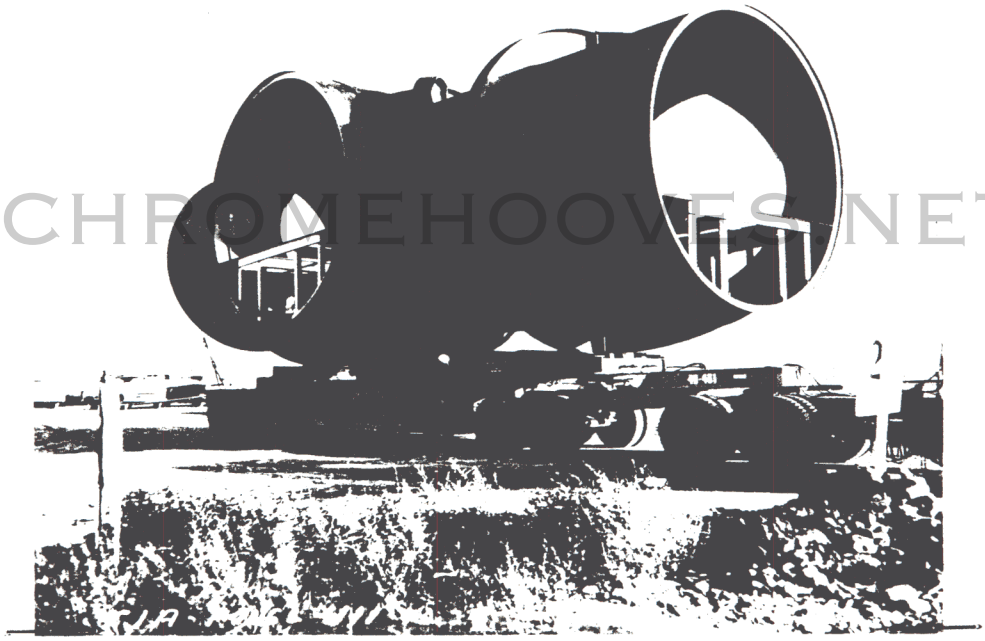
Diced basalt was determined to be the source of ground water. The provenance or source area adjacent to the complex is from generally a north and northwest direction. This upper basalt flow may receive irrigation water from higher elevations to the north and east near the Frenchman Hills upways or anticline where the basalt is at a higher elevation. Lithologically, the water-bearing zone consists of 14 feet of weathered, oxidized, highly fractured, pervious basalt, lying approximately between elevations 1165' and 1180' and between 24 and 35 feet below the average ground surface. It appears tenable that water will eventually rise to ground level as anticipated in the design.

The water problem at 1-C has been studied by all echelons within the Corps and the Air Force. Experiments in various methods of sealing off the leaks included checmical grouting, use of epoxy resin sealing compounds, and dewatering of limited areas by pumping of wells. Results have been turned over to BSD through CEBMCO for analysis. In the opinion of the Area Engineer the most positive and permanently effective means has been welding of leaking bolts and seams. However, the great amount of equipment

installed in tunnels and the use of concrete in tunnel inverts makes some leaks very difficult to reach.

At the time of turnover of Site 1-C, water leakage into structures was very limited, far below the design capacity of sump pumps. Waste from the site is pumped to ground level and carried off by gravity through a pipe line to a Bureau of Reclamation wasteway about 1¼ miles north of the site.

The acceptability of limited seepage is under discussion between BSD and SAC. At Air Force request the Seattle Engineer District has let contracts for chemical grouting of the metal tunnels and for construction of a permanent underground waste line to the Bureau of Reclamation wasteway.



Part of Tunnel Junction No. 10 on arrival at **Complex 1-A**, 16 February 1961. (Figure 22)

Complex 1-A - View Looking North at Blast Locks No. 1 and No. 2 and Interconnecting Personnel Tunnels. (Figure 23)

Complex 1-B, - View in Personnel Tunnel No. 12 showing Cable Trays, Piping & Lighting Fixtures. Ready for Concrete Placement for Walking. (Figure 24)

Complex 1-C - View Looking S E along B Tunnel towards Antenna Silos. (Figure 25)

17. SAFETY

Pre-CEBMCO:

As required by Corps of Engineers regulations, a pre-construction safety meeting was conducted prior to beginning of operations on each missile launching or support contract at Larson. At these conferences potential hazards of underground construction with particular reference to expected danger in the 165' deep Missile Silos were outlined to the contractors. Each prime contractor submitted a project safety program which was carefully reviewed and approved by the Area Engineer.

At the time that CEBMCO assumed control, the frequency of lost time accidents at Larson was 26.5 per million man-hours of exposure, approximately twice that of the National average for heavy construction. Several factors which contributed to the unfavorable frequency record were:

a. Corps and Contractor personnel were working under extreme pressure in view of the short time permitted for completion of construction.

b. The Chief, Construction Branch at Larson was assigned additional duty as Area Safety Engineer. In view of the urgent demands on his time in connection with his normal construction duties, the safety program was not receiving full attention. The Safety Engineer, Walla Walla District, furnished valuable support, but since his responsibility covered two missile areas plus various other civil and military projects, his assistance to this job was limited.

c. Although the Prime Contractor on contract 3552 employed a full-time Safety Engineer, this engineer was not given adequate support by the contractor's Project Manager. Lack of support of the Safety Program was reflected in the attitude of supervisors at the Site level.

d. The Corps of Engineers Safety Manual, although used as a guide in matters pertaining to safety, was used principally to correct deficiencies found by Corps inspectors and the Contractor's Safety Engineer rather than as a guide for a preventive program.

Post-CEBMCO:

Upon assumption of control of the Area Office by CEBMCO, a Safety Engineer was authorized in the area organization. In January of 1961 a full-time safety engineer was assigned to the Area. Upon his arrival, he was given full authority by the Area Engineer to set up and coordinate a comprehensive Area-wide accident program. Through the media of letters of instruction to the Prime Contractor; frequent conferences with the contractor's Safety Engineer; weekly, or more frequent, safety inspections at each Site; close follow-up on employee or supervisor's recommendations and suggestions for corrections of unsafe practices in work areas; attendance at weekly craft "tool box" meetings; and by generally being available to each Corps inspector, construction worker, or foreman, the accident rate at Larson began to improve greatly.

After the beginning of joint occupancy in the construction area in March 1961, the Area Safety Engineer, working with the Area Executive and Liaison Officer, organized and became a member of the Area and Site Integrated Safety Committee. At meetings of the committee Safety Engineers employed by the Air Force Associate Contractors and by The Martin Company discussed potential problems with the Corps Safety Engineer and, using the CE safety manual as the prime guide, established an integrated safety program which proved effective through the critical period of joint occupancy during which crowded conditions existed as members of a large number of crafts and indus-

tries working for as many as twenty different contractors jointly occupied tunnels and underground structures. As a result of this close cooperation between the Corps of Engineers and Air Force contractors and as a result of a realization by Associate Contractors of the value of established Corps procedures, based on long experience in the field of heavy construction, the authority of the Corps Safety Engineer was recognized as paramount in Areas not turned over to the Air Force, and an excellent safety record was established.

Generally, excellent cooperation was received from Corps contractors in the prosecution of the safety program instituted by the Area Safety Engineer. Aid stations, staffed by qualified personnel were set up at each work site and ambulances were on a standby basis at each complex. At the time that the number of Associate Contractor personnel in the complexes exceeded those employed by the Corps contractor, the responsibility for maintaining the aid station and providing the ambulance passed to the Martin Company. Arrangements for reimbursing The Martin Company for these services were made between MacDonald-Scott & Associates and Martin.

Summary:

As noted on the following chart indicating personal injury frequency rate for 1961 and 1962, the cumulative rate at Larson attained a figure of 1.25 per million manhours of exposure at the end of the job. No fatal accidents occurred to Corps or Contractor personnel at Larson and the final figure indicates a safety average considerably better than the National, Titan I, or CEBMCO average for heavy construction in spite of the extreme urgency and close working conditions which were encountered on this job.

The result of the safety program at Larson emphasized the need for strong safety orientation of all employees and for designation and wholehearted support of a single qualified person whose sole responsibility is safety.

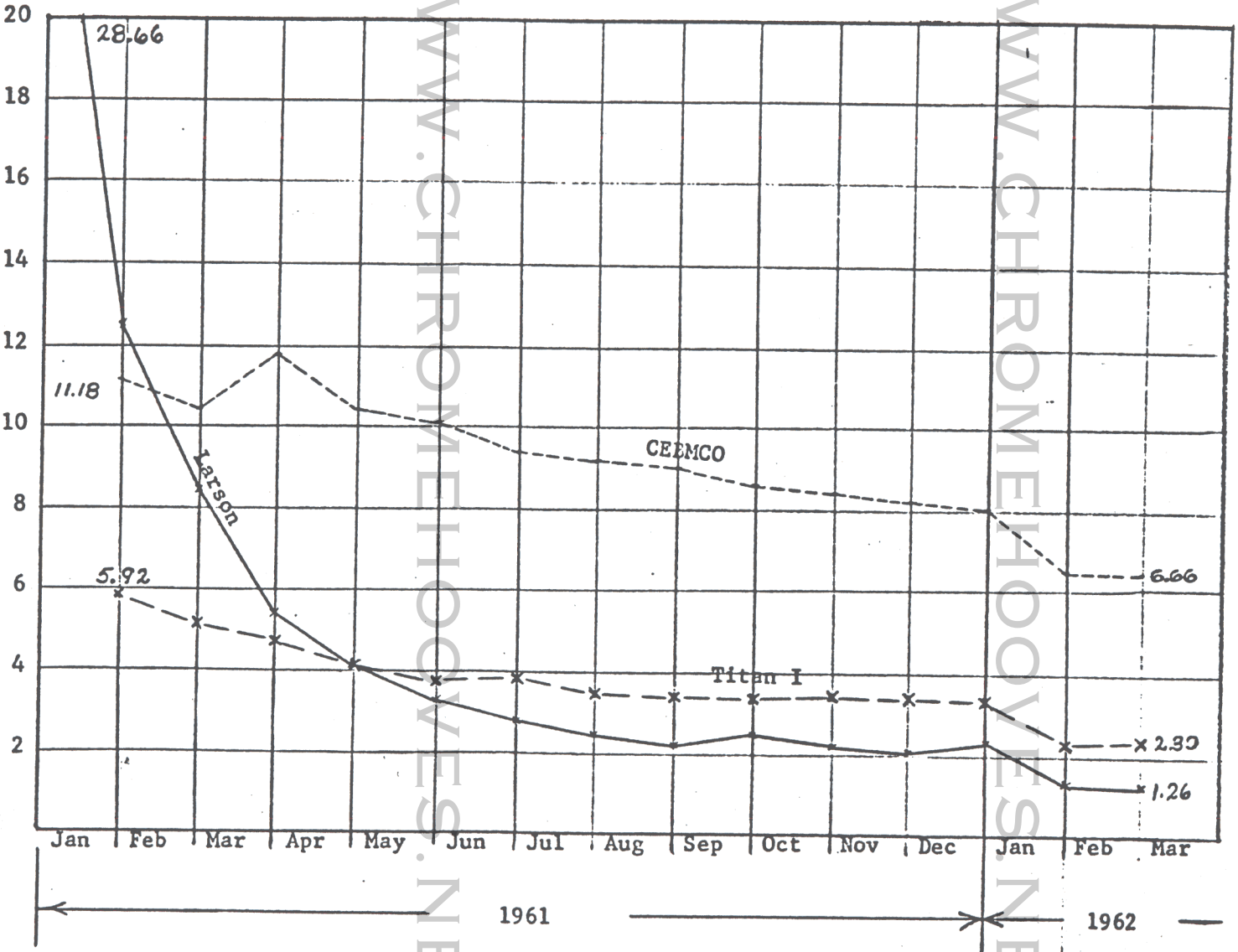


Fig 26

PERSONAL INJURY FREQUENCY RATE
(Lost Time Accidents per Million Man-Hours of Exposure)

18. SUBCONTRACTORS

Contractor-Subcontractor Relationship:

Approximately 30 to 40 percent of the work at Larson was performed by subcontractors. In the great majority of cases, the prime contractor selected reputable firms for subcontracts and relations were good. One source of friction between the prime and his subs were the delays in payment of the subcontractors while the prime contractor attempted to obtain additional funds from the Government to cover the work added to the original scope of the job or re-done to comply with changed design under the "concept of concurrency." Although the Area processed all changes and claims as rapidly as possible, certain unavoidable delays in payment or denial of requests occurred. The prime was not adequately funded to pay his subs prior to receipt of the Contracting Officer's decision. The Area's method of expediting payment by use of two-part modifications is covered in detail in Part III. Dealings between the prime and assigned suppliers of standardized equipment were not as favorable since the suppliers were not chosen by the prime and the feeling of mutual responsibility was not as firm. In several instances, particularly in dealings with the CompuDyne Corporation and the LOX Equipment Co., the Area Engineer was required to act as liaison between the prime and his sub.

Effect of Subcontracting on Job:

Subcontracting by the prime was well within the normal standards of the construction industry as the average firm or joint venture could not be expected to have at its disposal the variety of skills and equipment required to perform so complex a job. Subcontracts let by the prime had no unusual effect on the efficiency or cost of the job. The assignment of standardized

equipment contracts to the prime did have an adverse effect on the efficiency and cost of the job as pertains to the LOX and CompuDyne contracts and to a lesser extent as pertains to the Trane contract. Delays and extra costs in these cases were kept to a minimum by prompt action by the Area Engineer and by CEBMCO. Generally good relations and consequent efficiency were encountered with other standardized equipment suppliers, but the policy of assignment of Government contracts does not appear practical in the light of experience at Larson. Subcontracting by primes for on-base support work produced no problems.

List of Principal Subcontractors:

Following is a list of principal first and second-tier subcontractors:

Firm	Type of Work
Donald W. Close Company 2921 - 13th SW Seattle, Washington	Electrical
Meehleis Steel Co. 5400 Alcoa Ave. Vernon 58, California	Furnish and install Reinforcing Steel
Pre-Mix Associates 805 N. Division Spokane 2, Washington	Furnish all Concrete
Anchor Fence Div. Anchor Post Products 4502 - 14th Ave. NE Seattle 7, Washington	Furnish and install Security Fencing
Murphy Brothers E. 3728 Broadway Spokane, Washington	Excavation and Backfill
(Sub) Cherf Bros. & Sandkay 103 - 12th St. SW Ephrata, Washington	Common excavation only on Site 1-B and common & rock excavation on Site 1-C

(Sub) Northwood-Mannix 1768 E. Hasting Vancouver, Washington	Silo excavation on Sites 1-B and 1-C
Columbia Basin Waterproofers P. O. Box 236 Ephrata, Washington	Waterproofing and damp- Proofing
Fiberglas Engr. & Supply 1248 Sixth Ave. So. Seattle 4, Washington	Furnish & Install Insulation
Ree-Son, Inc. 52 E. Campbell Ave. Campbell, California	Painting
R. L. Stevenson Co. 911 Western Ave. Seattle 4, Washington	Painting
Johnson Service Co. E. 7 Riverside Ave. Spokane, Washington	Furnish and Install PLS Instrumentation
Otis Elevator Co. 260 - 11th Ave. New York 1, N. Y.	Furnish and Install Elevators
Fox-Detweiller 4630 Vine Street Denver 16, Colorado	Furnish and Install Ventilating System & Ducting
The Brower Co. 114 Virginia Ave. Seattle, Washington	Furnish and Install Accoustical Ceilings & Baffles
Weber Showcase & Fixture Co. P. O. Box 15445 DeSalle Sta. Los Angeles 15, California	Furnish Metal Doors and Frames and install Builders Hardware
Elite Shade & Linoleum Co. 2929 Blakely Street Seattle 5, Washington	Furnish and Install Asphalt Tile, Vinyl Tile, Etc.
S & S Sand & Gravel, Inc. Ephrata, Washington	Asphaltic Concrete Paving
(Sub) L. W. Vail Co., Inc. P. O. Box 847 Pasco, Washington	Asphaltic Paving

General Machinery Co. P. O. Box 4227, Sta. B Spokane, Washington	Furnish Blast Valves, Blast Doors and alied Hydraulic Systems
Early Engineering Corp. P. O. Box 218 Moses Lake, Washington	Operation & Maintenance of Compressors & Liquid Nitrogen Converters (rechargers)
CompuDyne Corporation	Furnish Valves for PLS
LOX Equipment Company	Furnish Cryogenic Vessels
Keenan Pipe & Supply Co.	Furnish Pressure Vessels
Nordberg Mfg. Co.	Furnish Diesel-Electric Generators
Federal Pacific Company	Furnish Electrical Controls
The Trane Company	Furnish Chillers & Ice Banks
Joy Equipment Company	Furnish Air Compressors
G. M. Wallace & Company	Furnish Pumps