CHAPTER VI

CONSTRUCTION HISTORY

Contractor's Organization. Kaiser-Raymond-Macco-Puget Sound, the prime Contractor, established a central office in the town of Mountain Home, Idaho. The local organization was under the direction of Mr. C. P. Bedford, Jr., Resident Manager. See Appendix No. 9, Sheets 1 through 7, for the prime Contractor's detailed organization chart.

Contractor's management was adequate in the higher echelon and the job was pursued with vigor. Due to the remoteness of the complexes, site management and lower level supervision left much to be desired, primarily because the better caliber people could secure positions in more desirable locations. Adverse climatic conditions and the non-availability of housing close to the sites contributed to this problem.

Subcontractors. See Appendix 10 for tabulation of subcontractors including approximate original contract price and scope of work.

In general, they possessed sufficient financial resources to carry them through an average job; however, the multiplicity of changes increased contract time and inability to negotiate equitable settlements, modifications, and claims with speed and merit, hampered the all-out effort of not only the subcontractors but the prime Contractor as well. Had not the prime Contractor been a large firm with practically unlimited resources, they, too, would have encountered considerable difficulty in completing their contract on time.

The Contractor sub relationship was good, with the prime expending considerable effort and money in helping the subs maintain their schedule.

Lack of money was the one major difficulty experienced by all the contractors, including the subcontractors assigned to the prime for the purpose of furnishing standardized equipment.

Subcontracting tended to lengthen communication lines, slowed down start of changes, increased cost, increased confusion, reduced Government control, and, in general, reduced the efficiency of the operation. Errors of the subcontractors were hard to pin down and caused extra work and delay in producing the finished product.

Preliminary Work. Mobilization of personnel and equipment and the preparation of construction and shop drawings was started in early February 1960, immediately after award of the contract to the joint venture of Kaiser-Raymond-Macco-Puget Sound. KRMPS set up offices, warehouse facilities, and a fabrication yard in Mt. Home, Idaho. Immediate communications were established by means of short wave radio and supplemented by telephone at a later date when commercial service became available. Areas adjacent to each complex were stripped and graded to serve as light plane runways. On-site survey and layout, based on control established by the Corps of Engineers, was started in late February at all sites. Fuel tanks were immediately installed and Contractor and Government offices consisting of specially constructed house trailers were provided.

Open Cut Excavation. Open cut excavation including rock excavation at Complex A was subcontracted to Wells-Cargo, Inc. The Contractor's approved excavation plan called for 3/4 to 1 slopes and excavation to a depth varying from 40 to 50 feet below the existing surface. Slopes were steepened at Complex A in solid rock and changed to approximately 1-1/2 to 1 at Complex B because of non-cohesive materials. Excavation at all sites was carried to the top of tunnel openings in missile silos, to the top of personnel tunnels at the propellant and equipment terminals, to the invert elevation of the antenna terminal, and varied from top of top foundation slabs to bottom of the tunnel and tunnel junction entrances to the control center and powerhouse structures. Numerous ramps were provided at each site to permit efficient use of heavy equipment. Tunnel trenching work was accomplished by KRMPS after concrete work on the main structures had progressed to an elevation above the tunnel levels.

Originally scheduled completion dates were staggered at one month intervals for Complexes A, B, and C in that sequence. This order was reversed at the Contractor's request by Modification No. 1 because of the more difficult excavation operation at Complex A. Stripping and open-cut excavation work was started at Complex A on 29 February 1960, at Complex C on 4 March 1960, and at Complex B on 16 March 1960. Work progressed on a two ten-hour shift, five day per week basis at all sites. Excavation equipment was transferred from site to site as required by job conditions and the Contractor's work schedule. All open-cut excavation was completed by 25 May 1960, at which time approximately 1,800,000 cubic yards of material, including 450,000 cubic yards of rock at Complex A, had been moved and stockpiled.

Excavation with heavy equipment and without blasting was possible at Complex A to a maximum depth of 28 feet in a portion of the launcher area. Solid rock was encountered at the surface in the powerhouse, control center, and antenna silo areas at this complex. Progress was handicapped at first by frozen ground and later by large boulders which were dug out by D-8 dozers equipped with rippers. Boulders were pushed to one side and loaded onto trucks with 2-1/2 yard shovels. Scrapers were released on 15 March for work at other sites.

Drilling and blasting work started on 11 March using a truck-mounted Joy drill and truck-mounted Schramm rotary rig capable of drilling 6-1/4 inch holes. Rock shattered well and progress was good except when slowed by inclement March weather. Ammoniam nitrate was used for blasting with maximum lifts of 20 feet. Rock was loaded with 2-1/2 yard Northwest and P & H shovels and hauled to spoil areas with Euclid and Payhauler dump trucks. Open-cut excavation was completed on 25 May 1960, except for tunnel trenching.

Open-cut excavation started at Complex B on 16 March 1960, and was completed on 5 May 1960. No rock was encountered at this site. Material consisted of sandy gravel, gravely sand, clay and some layers of fine sand. It was found during the first shift that the side slopes would not stand at the anticipated 3/4 to 1 angle and had to be sloped to 1-1/2 to 1. This change increased the excavation quantity to nearly 700,000 cubic yards at this site. Material loaded easily and excavation was rapid and without incident except for a severe dust and blow sand problem that occurred during periods of high winds.

At Complex C, open-cut started on 4 March 1960, and was completed on 19 April 1960. Material consisted of gravely sand, sandy silt, sandy silty clay, and silty clay. Side slopes were excavated to 1/2 to 1. Material loaded easily and excavation was rapid. Some slowdown was experienced during spring rains because of muddy conditions and slick haul roads. All excavated material was moved into two separate stockpiles immediately adjacent to the area. No unsatisfactory material was encountered and all excavated material was used in the backfill operation. Rock removed from the silos was utilized in levelling the site area.

A representative list of equipment used for excavation follows:

Complex A

1 Manitowac 3900 Crane
1 HD 21 Dozer w/ripper
1 Bantam Backhoe
1 Lima Crane
8 Euclid Trucks (dump)
6 Payhaulers Trucks (dump)
1 HD-15 Skip Loader
2 NW 80-D Shovels
1 P & H Shovel
1 Motor Patrol
5 Air Track Drills
1 Schramm Drill
1 Cat-mounted Drill
1 Loraine Crane
1 Michigan Loader
1 Jumbo Drill Rig
1 EIMCO Loader

Complex B

8 DW-20 (28-yard)
2 DW-21 (21-yard)
5 D-8 Cat Dozers
1 D-12 Motor Patrol
2 Letourneau C-3 (22 yard dump truck)
1 Manitowac 60-ton Crane
1 Lima 20-ton Crane
1 Loraine 20-ton Mobile Crane

Complex C

4 D-8 Tractors
1 Manitowac Crane w/3-yard Clam
2 Euclid end-dump trucks
1 Lima 20-ton crane
1 EIMCO Loader
1 Loraine 35-ton Crane
1 M-F "Work Bull 303" Front End Loader & Backhoe
1 Gradall (Warner & Swansen)

Shaft Excavation. Shaft excavation started in each of the launcher areas as soon as open-cut excavation was complete in that area. Shafting work was accomplished by the prime Contractor. Work began at Complex C in March 1960, and was completed August 1960 at Complex A.

A total of 114,000 cubic yards of material was removed during this period. Included in this amount, 14,000 cubic yards of solid rock, most of which was encountered at Complex A. Work was accomplished at the various sites as follows:

	Started Collar Beams	Started Line Drilling	Completed Shafting	Cubic Yd Common Material	Cubic Yard Rock	Cubic Yard Total
Complex A	23 Mar	4 Apr	16 Aug	21,340	11,590	32,930
Complex B	4 Apr	12 Apr	22 Jun	35,760		35,760
Complex C	21 Mar	28 Mar	2 Jul	33,016	2,028	35,044
				100,116	13,618	113,734

Forming and placing of the reinforced concrete collar beams marked the actual start of shafting operations. These beams were circular in shape, 6 feet wide, and 3 feet deep. They were located flush with the surface and placed so that the inside edge coincided with the desired location of the shaft walls. For purposes of safety, a 5-foot chain link fence was installed around the top of the shaft. Catch ladders were used with landings each 20 feet.

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Line drilling around the entire perimeter of the shaft was required by the specifications wherever blasting was necessary. Holes 2-1/2 inches in diameter were drilled on 5-inch centers to a depth of 20 feet for each lift. A jumbo drilling rig specially designed for shafting work was used for some of the work but it was found that better results could be obtained with Air-Trac drill rigs. As many as four drill rigs would be used simultaneously and were easily lifted in and out of the shafts with cranes.

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Blasting was accomplished in accordance with an approved blasting pattern which provided for a relief hole at the center. Time delay electric caps were arranged so that detonation occurred from the center outward. Blasting was done in 5-foot lifts using approximately 1/3 lb. of ammonium nitrate per cubic yard of rock.

Sixty-ton Monitowac cranes equipped with 1-yard clamshells were used for mucking to depths ranging from 30 to 60 feet depending upon material encountered. EIMCO front end loaders loading into skips were used at the greater depths when clamshell operation became uneconomical. A segment of the shaft was partitioned off with an I beam and lumber framework behind it. The clamshell skip was lowered to pick up material. Personnel were required to leave the shaft when heavy equipment was raised or lowered. Material was transported to stockpile or spoil areas by 14-yard C-pulls and 18-yard rear dump Euclids.

Rock was so badly fractured and seamed that rock bolts could be used only in limited amounts. Ring beams, placed at maximum intervals of 6 feet were used to contain the shaft walls. Walls were trimmed with jackhammers or pneumatically operated spades and ring beams suspended on bolts from the collar beam, were blocked into position. A 2" x 2" x 12-gage reinforcing mesh was placed behind and in contact with the beams. Gunite was used to fill all voids between the ring beams and excavated wall surfaces, with care being taken to cover the reinforcing mesh and avoid deposits in the inside surface of the beams. The use of intermediate beams was sometimes necessary where free flowing sand was encountered. Shaft excavation varied in depth from approximately 20 feet at the propellant terminals and antenna silos to 120 feet at the missile silos. No ground water was encountered during any portion of the excavation.

Bearing Tests. Bearing tests were conducted in the powerhouse and control center foundation areas at Complexes B and C as soon as open-cut and fine grading work had been completed in these areas. No tests were performed at Complex A because of the solid rock conditions. Test locations were specified by the Corps of Engineers, test set-up was accomplished by KRMPS, and the tests were conducted by Gem State Testing Laboratories of Boise, Idaho. Foundation material was progressively loaded to 75,000 psi with load versus settlement recorded for varying time periods. All tests indicated that the foundation material was adequate.

Backfill. The Corps of Engineers soils laboratory did all testing work for both earthwork and concrete. Compaction curves were established in the laboratory located at the Air Base. Laboratory personnel were located at each of the sites for the purpose of obtaining compaction samples during backfill operations. Constant changing of materials encountered at Sites A and B required the lab personnel to make check points on the material being compacted and also to make compaction curves during backfill operations. Material at Complex C was nearly the same at all times and did not require as many compaction curves as did the other two sites. The contract required densities, as measured by the modified AASHO method, of 90% in open fill areas and 95% in tunnel bedding, subgrade under crane pads, subgrade under roads and parking areas, and crushed base course in roads and parking areas. Compaction requirements for structural foundations varied from 92% for cohesive material predominate at Complex C, to 95% for cohesionless material which was encountered at Complexes A and B.

Compaction was accomplished by the use of sheep's foot rollers, self-propelled vibratory rollers and rubber tire rollers. Hand operated vibratory compactors and pneumatic tampers were used in tight locations. Material was placed in 8" lifts which were compacted to 6 inches. The first area to be backfilled was around the antenna silos and the B tunnels from the antenna silo to the powerhouse area. Backfill was continued in other areas after concrete operations were sufficiently advanced.

Extreme care was taken during backfill under and adjacent to tunnels and tunnel junctions. Areas below tunnels were graded and brought to 95% compaction. Material was removed to allow for ring and yoke beams. Particular care was taken to insure that required compaction was obtained under the inverts and immediately adjacent to the sides of the liner plate. This portion of the work required a great deal of hand effort. Tests for compaction and moisture were taken 3 to 5 tests per lift in the 95% areas and 2 to 3 tests per lift in the 90% areas. Moisture was checked very closely during backfill operations. On-site material at Site A was unsatisfactory for this purpose and it was necessary to obtain sand from a nearby borrow area. In spite of these precautions, some voids were found when test sections were cut from the tunnel liner plate in the inserts of some of the tunnel junctions. This situation was corrected by pressure grouting when necessary. B tunnels were strutted prior to compaction and struts removed when backfill was at least 10 feet abovethe top of the tunnel. Surveys were taken at periodic intervals. There were no settlement problems at any site and there was no visible distortion or failure of any structure.

Source of aggregate for the crushed base course differed at each of the complexes. Material at Complex A was crushed from the excavated rock and blended with sand to meet the required gradation. Material for Complex B was crushed from a gravel pit near the site and the material for Complex C was crushed 20 miles from the site and hauled in large dump trucks.

Bituminous surface course was mixed from one stationary paving plant and transported in insulated trucks; loads were tightly covered with roofing paper and canvas. Testing was in accordance with the Marshal control.

Concrete Mix and Materials. Batch plant work was subcontracted to Boise-Cascade. Plants were set up on the work sites at Complexes A and C and adjacent to the access road 1.7 miles from Complex B. Batch plant facilities were completed at Complex A on 3 June 1960, at Complex B on 7 June 1960, and Complex C on 9 May 1960. Plants were of the semi-automatic type with bins for cement and 3 sizes of aggregate and had capacities of 60 cubic yards per hour. Cement, aggregate, and water were loaded into 3-1/2, 5, and 7 yard transit-mix trucks for mixing and transportation. Pretested cement obtained from Lime, Oregon, was used throughout.

Aggregate for Complexes A and B was obtained from the Yarbrough Pit on the Snake River north of Grandview. Haul distances were 45 miles and 7 miles, respectively. Aggregate for Complex C was hauled

25 miles from the Nelson Pit in Boise.

Water was obtained for all plants from the deep wells located at the work sites. An attempt was made at Complex B to obtain water at the batch plant. A 550-foot well was drilled for this purpose but the water was found to be unsuitable for use in concrete. Water was finally obtained by laying a pipeline to the site. Spray ponds were used during warm weather to cool the 168° water.

Design Mix. Concrete mix designs were developed for 1-1/2 inch and 3/4 inch minus aggregates in strengths ranging from 2,000 psi for Class C to 5,000 psi for Class AAA concrete. Water-cement ratios varied from .58 to .34 and cement from 4-1/2 to 8.3 sacks per yard. Concrete specimens were cured in spray changers at each site. Cylinders were broken in the Corps of Engineers' soils laboratory.

Cement was obtained from the "Sun" plant at Lime, Oregon. That used at Complex A was shipped by rail to Mountain Home, then hauled by truck to the site. Cement for Complexes B and C was shipped by truck from Lime directly to the sites.

Concrete Manufactured at Batch Plant Complexes A & B
Materials to Make 1 Cu. Yd. of Concrete (WTS SSD)

Class Concrete	Cement Sacks	Water Gallons	Sand	Pounds of Aggregate # 4 - 3/4"	3/4" - 1/2"	% Air
C	4.6	27.5	1223	952	1032	4.5
A	5.5	27.3	1182	939	1021	4.5
AAA	7.0	29.2	1078	912	994	4.5
A	6.0	31.8	1267	1736		4.5
AAA	7.2	31.7	1229	1684		4.5
A	6.4	28.9	1113	923	1002	4.5

Concrete Manufactured at Batch Plant Complex C
Materials to Make 1 Cu. Yd. of Concrete (WTS SSD)

Class Concrete	Cement Sacks	Water Gallons	Sand	Pounds of Aggregate #4 - 3/4"	3/4" - 1-1/2"	% Air
A	6.0	35.2	1214	1714		4.5
A	6.5	41.3	1293	1488		4.6
AAA	7.5	34.7	1197	1653		4.5
AAA	8.25	34.4	1147	1650		4.5
A	6.4	30.9	1100	955	966	4.5
C	5.0	28.2	1210	987	995	4.5
AAA	7.0	31.6	1035	961	968	4.5
A	5.5	29.2	1156	984	992	4.5
A	6.0	31.1	1035	1004	1012	4.5
AAA	7.5	32.2	988	958	966	4.5
C	4.5	29.4	1230	981	992	4.5
AAA	8.0	30.7	956	971	978	4.5

Concrete Placement. Concrete work started at Complex C on 1 June 1960, with placement of the foundation slab for equipment terminal No. 2. The last pour was made at Complex A on 13 October 1961, and consisted of the upper door curb on missile silo No. 3. During this period, a total of 31,650, 34,000, and 33,590 cubic yards were placed at Complex A, B, and C, respectively. Variations in quantities were primarily due to differences in foundation design.

Concrete was placed with an average slump of two inches. Concentration of heavy reinforcing steel in such locations as the top of the missile silos made placement extremely difficult in some instances. A 3/4 inch minus mix was used in such locations and special care was taken with arrangement and sequence of placing reinforcing steel, to permit placing and vibrating the concrete.

Concrete was placed in the missile silo barrels by the slip-form method. This work was subcontracted to Hansen-Kashner. Slip-forms were constructed in Mountain Home and moved to the sites when needed. Placement of slip-form concrete started at Complex C in missile silo No. 2 on 5 August and was completed at Complex A on 19 October 1960. Slip-forms were 40 feet in diameter, four feet deep, and were suspended from a total of 18 one-inch steel rods anchored to outriggers at the surface. Forms were constructed with an upper platform for concrete finishers. Guide rails were established at each quandrant for maintaining form alignment.

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Concrete was lowered in 3/4-yard hoppers to the working platform by means of winches and distributed with buggies. Movement of the form was controlled by pneumatic jacks placed on each of the steel support rods. Jacks were equipped with holding and lifting dogs which took a 5/8 inch bite. Jacks could be controlled individually and as a group by a master control panel.

The slip-form was moved at a maximum rate of approximately 12 inches per hour. The maximum 24-hour pour was 20 feet; however, the average rate of progress including down-time was about 10 feet per day. Slip-form operations were continuous except for occasional week-end shut-downs, and 3-1/2 yard transit mix trucks were used to keep standby time to a minimum.

Control center and powerhouse domes were placed with specially designed Blaw-Knox steel forms. These forms were supported at the

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center by a structural steel frame work that remained in place until the dome was completed. Each set of forms had two 45^{o} wing segments equipped with jacks and rollers to permit easy positioning. The wings were supported by a system of trusses fastened to the inside form and constructed to span the distance from the center support to the foundation.

The first pour was placed with wing segments located diametrically opposed in order to equalize the loading; wings were then rotated for additional pours. The segment including the tunnel opening was placed last using wood blockouts for the opening and wood forms for the thickened section. It was found during placement that many additional access panels were necessary in order to properly place and vibrate the concrete. It was also found that better results could be obtained at the top of the dome by omitting the upper one-third of the outer form.

A total of two forms, one for the control center and one for the powerhouse, were provided. These forms were moved from site to site as required. Transportation and erection required from two to three weeks. A schedule of concrete placement follows:

Powerhouse	Start	Finish
C	28 Oct 60	2 Dec 60
B	22 Dec 60	21 Jan 61
A	9 Sep 60	12 Oct 60
Control Center		
C	6 Sep 60	20 Sep 60
B	16 Nov 60	10 Dec 60
A	11 Oct 60	31 Oct 60

The walls of equipment, propellant, and antenna terminals, and air exhaust and intake structures were placed in 10-foot lifts with a combination of steel and wood forms. Universal forms were used for external forms when the pour was above the ground level. Roof and foundation slabs were as much as six feet in thickness and heavy shoring extending to foundation level was provided for the extremely heavy roofs.

All intermediate floor slabs were designed to float on a complex shock mounting system. Slabs in the powerhouse at Sites B and C and control center at Sites A and B were placed on shoring, then lowered onto the spring beam shock mounts at a later date. This method was used to avoid delays while waiting arrival of spring beams. Remaining slabs were poured in place on the spring beams. Coil spring shock mounts in the propellant terminals were blocked during placement of the slab. Shocks were not loaded until all heavy equipment had been placed.

<u>Silo Doors</u>. Missile, antenna, and portal silo doors were reformed and poured in place as soon as pillow block and door shafts had been installed. This work was delayed on the missile silos because of defective welds which were found between the sole and side plates of the pillow block mounts. These defects first became apparent when an I&C contractor welded the missile silo pillow blocks to the mounts. This welding caused warping of the sole plate and resulted in visible failure of the pillow block mount at several locations. All mounts were checked by Ultrasonic and Magnaflux equipment to determine the extent of failure. Repairs were accomplished by removing defective

welds with air-arc equipment and repairing with stainless steel rod. This work was accomplished on an expedited basis to avoid delaying placement of the doors.

Missile silo doors were placed after the installation of the LOX and fuel cribs by the prime Contractor. Doors were raised as soon as possible to provide ventilation and access to the silos for other work. Class AAA concrete with a compressive strength of 5,000 psi in 28 days was used on these doors. High early cement was used on all doors to expedite this phase of the work. Missile silo doors were opened by the prime Contractor by means of cantilever beams and a spreader bar. Doors were lifted to the 70° position with two cranes; at this point, a third crane placed directly behind the door was used to swing the door into the final position. Antenna silo doors were opened with hydraulic drive cylinders borrowed from the portal silos and actuated by a portable pumping system. Portal silo doors were opened by means of the permanent door opening mechanism. All doors were opened without accident either to equipment or personnel.

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<u>Curing</u>. Lift joints were either sand blasted or cleaned with an air water jet then buttered with a grout mix immediately preceding the next pour. Curing was obtained by a number of methods including water, polyethylene, and curing compounds. Contractor attempted to use curing compounds in the missile silos during slip-form operations but this method was discontinued because of the severe fire hazard and silos were water cured throughout.

Removal of forms from structural concrete varied from 4 to 10 days after placement, depending upon strength of job-cured cylinders.

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In some instances, forms were left in place to aid in curing.

Winter Operations. Batch plants were winterized by inclosure of the aggregate piles and plant areas. Water heated to 150° F was used in the mix during cold weather, and aggregate bins, stock piles, and operating areas of the plant were heated by space heaters. Water was heated at Complex C by means of a butane-fired water heater and a booster coil was used at "A" to increase the temperature of the 128° F well water when necessary. The temperature of the artesian water at Complex B could be maintained at approximately 155° by allowing continuous flow; water from the cooling pond was mixed as necessary to obtain the desired temperature.

Concrete was protected during the winter months by canvas covers with oil or butane fired space heaters. At Complexes A and B, the natural hot water was used for curing purposes and cold weather protection. The only damage due to freezing occurred at Complex B where a portion of a concrete pour at Elevation U was left exposed on a missile silo. Only minor repairs were necessary.

Reinforcing Steel. Supply and installation of all reinforcing steel was subcontracted to Gilmore-Skoubye steel contractors. The steel was shipped by rail to Boise where it was cut and fabricated by Gem State Fabricators. It was then shipped by truck from there to the sites.

Virtually all resteel was placed in strict accordance with contract drawings. It was necessary in some instances, such as the 50-ton vertical jack pedestals in the missile silos, to install additional steel because of omissions on the contract drawings. Complicated stirrup designs in such places as the missile silo door and LOX bay foundations were altered to facilitate placement in the field. A representative of the designer (DMJM) was available during the early part of the work to review resteel changes.

<u>Post-Tensioning</u>. Contract drawings called for post-tensioning of the foundation footings of the control centers at Site B and C. This work was subcontracted to Preload Company, Inc., who accomplished the job after the domes had been placed. Eighteen-gage high strength steel wire was stressed to approximately 150,000 psi and wrapped around the foundation with a special wrapping machine. Spacer bars were utilized to maintain proper distance between wires. Wires were grouted into position after completion of the wrapping process. The total prestressing operation took seven weeks at Complex C and three weeks at B.

<u>Structural Steel</u>. Structural steel work was subcontracted to Isaacson Ironworks at Seattle, Washington. Steel was shipped ready for assembly by a combination of rail and truck. Workmanship was excellent and very little difficulty was experienced during assembly.

Eaton Metal Company of Denver, Colorado, contracted the tunnel sections, tunnel junctions, antenna terminal, launcher air filtration structure, the LOX tank structure, propellant and equipment terminal access stacks, and all personnel and utility tunnels. Tunnel sections were inspected at the source in Denver and Salt Lake City, dampproofed and transported by truck and rail to the assembly yard in Boise, Idaho. The larger structures were shipped in sections and assembled in Boise. Considerable correction was necessary due to damage and misalignment.

Additional dampproofing was applied where necessary before being sent to the sites.

<u>Tunnels</u>. The 8-foot nominal diameter five-gage multiplate "B" Tunnel was fabricated in approximately 50-foot lengths and asphalt coated on the exterior surface, complete with pipe supports on 7-foot centers, at the Eaton Metal Company, Salt Lake, Utah, plant. These tunnel sections were then trucked to the sites where unistruts on 3-foot centers were welded in place to suppprt electrical conduit.

The initial work of installing these sections of "B" Tunnel and bolt-up the connecting ends was accomplished by Isaacson Ironworks of Seattle, Washington, at Site C. At that time it was found that the pipe supports began to progress from the designed vertical plane toward a horizontal transverse plane. The pipe support problem resulted when a uniform helix twist developed in the tunnel as additional sections were bolted together. All subsequent installation of the "B" Tunnels was then accomplished by the prime Contractor. After several unsuccessful attempts were made to twist the tunnel sufficiently to bring the pipe supports into correct position, most of the supports were removed and rewelded to correct this problem.

The tunnels were strutted out-of-round approximately 1% prior to backfill placement. Every reasonable effort to strut the tunnels the specified 3% failed due to the reinforcement factors provided by the welded pipe supports and conduit unistrut. The struts were removed after backfill had been placed to an elevation of at least 10 feet above the top of the tunnel to make these areas available for other work.

modification.

<u>Modification No. 97</u> was issued on 2 May 1961, for additional pipe supports for the PLS piping to correct a design inadequacy. The Contractor's original proposal of 8 September 1961, in the amount of $227,160.00 was revised upward on 19 September 1961, to $273,780.00. Negotiations were conducted on 19 September 1961, at which time an amount of $208,000.00 was agreed to be an equitable adjustment in the contract amount for the changes involved.

<u>Modification No. 109</u> was issued 9 June 1961, to provide for additional pipe supports in tunnel junction No. 12 to provide adequate shock supports. The Contractor's original proposal of 16 October 1961, was for $236,254.00. During negotiations on 8 November 1961, a settlement was made in the amount of $167,000.00.

<u>Modification No. 129</u> was issued on 4 August 1961, to provide for the Contractor to handle and transport all the Government furnished liquids and gases from the Mountain Home Air Force Base to the construction sites. The Contractor's original proposal of 20 October 1961, in the amount of $140,476.00 was revised on 30 November 1961, to $161,068.00. During negotiations on 25 January 1962, the Contractor revised his proposal to $168,350.00. The modification was settled on 2 7 January 1962, for $125,000.00.

<u>Modification No. 133</u> was issued on 25 May 1962, to provide reimbursement to the Contractor for additional acceptance tests. The Contractor's original proposal for the Claim No. 256 portion was submitted 13 April 1962, and was for $712,082.00. Negotiations were

conducted on 20 April 1962, at which time the Government offered to settle Claim No. 256 for $116,720.00. On 23 April 1962, the Contractor declined this offer. During negotiations on 26 April 1962, it was agreed that Case No. 182 would be combined with Claim No. 256. Settlement was reached for a total of $639,000.00, allocating $404,000.00 to Case No. 182 and $235,000.00 to Claim No. 256 (Case No. 353).

Modification No. 140 was issued 9 August 1961, to provide for replacement of expansion joints in tunnel junction No. 10 with flexible hoses. The Contractor's original proposal of 3 February 1962, was for $397,196.00. During negotiations on 14 March 1962, the Contractor revised his proposal to the settled amount of $257,600.00.

Modification No. 144 was issued on 22 August 1961, to provide revisions to the RP-1 fuel system. The Contractor's original proposal of 11 November 1961, in the amount of $141,705.00 was revised and resubmitted on 7 December 1961, in the amount of $125,888.00. Negotiations were conducted on 30 November 1961, and 21 December 1961. The modification was settled for $103,000.00.

Modification No. 163 was issued on 13 October 1961, to provide for revisions to the blast valves. The Contractor's original proposal of 10 January 1962, was for $707,178.00. Negotiations were conducted on 5, 9, 17, 23, 27 February 1962, and 1 March 1962. The modification was settled for $249,500.00 on 1 March 1962.

Modification No. 164 was issued on 22 November 1961, to reimburse the standardized equipment contractor for the amount claimed due for accomplishing the recleaning of the PLS valves and related equipment. Settled amount was $252,000.00.

Modification No. 173 was issued on 3 November 1961, to provide for spare parts for PLS valves and equipment to avoid delays in testing in case of failure during testing. The Contractor's original proposal of 8 February 1962, was for $247,180.00. Modification No. 173 was settled 1 May 1962, for $183,400.00

Modification No. 191 was issued 14 February 1962, to provide for revisions to the pipe supports in the utility tunnels in order to correct a design error and to provide additional supports for blast lock floors to comply with shock requirements. The Contractor's original proposal of 7 February 1962, was for $851,000.00. Negotiations were conducted on 17 and 22 February 1962, with a final settlement agreed to during negotiations on 17 March 1962, in the amount of $508,180.00.

Modification No. 205 was issued 2 April 1962, to provide reimbursement to the Contractor for costs incurred to accomplish work claimed to be in excess of the contract requirements with respect to PLS components. The Contractor's original claimed amount due was $683,801.00. Negotiations were conducted on 17, 18 January 1962, 20 February 1962, and 3, 7, and 21 March 1962. Final agreement amount was $295,167.00.

Modification No. 210 was issued 4 April 1962, to provide reimbursement to the Contractor for furnishing and installing 720 additional shock mount pads for the fire water system in the missile silos. The Contractor's original proposal of 7 March 1962, was for $421,582.00.

Negotiations were conducted on 21 and 22 March 1962, with final agreement reached on 26 March 1962, in the amount of $200,000.00.

Modification No. 216 was issued 11 April 1962, to provide reimbursement to the Contractor for furnishing and installing 255 square and 2,310 round shock mounts for the missile silo fire water systems. The Contractor's original proposal dated 20 March 1962, was $858,929.00. During negotiations on 30 March 1962, the Government proposed the amount of $371,300.00 as an equitable settlement for Claims 179 and 255. On 2 April 1962, the Contractor accepted the Government's offer of $371,300.00.

Modification No. 229 was issued 11 May 1962, to provide reimbursement to the Contractor for numerous mechanical changes in the powerhouses. The Contractor's original proposal of 15 February 1962, was for $1,497,027.00. Negotiations were conducted on 19 and 20 April 1962, with final agreement reached in the amount of $485,000.00.

Modification No. 233 was issued on 25 April 1962, to provide reimbursement to the Contractor for revised flexible hoses. The Contractor's original proposal dated 11 April 1962, was for $451,215.00. During negotiations conducted on 24 April 1962, the Government offered to settle for $202,646.00 which was accepted by the Contractor on 26 April 1962.

Modification No. 234 is being issued to provide reimbursement to the Contractor for acceleration costs for tunnels and tunnel junctions. The Contractor's original proposal dated 22 March 1962, was for $719,405.00. During negotiations conducted on 27 April 1962, the

Government made an offer of $550,000.00 which was accepted by the Contractor on 30 April 1962.

Modification No. 238 was issued 23 May 1962, to provide reimbursement to the Contractor for revisions to tunnel and tunnel junction and supports. The Contractor's original proposal of 8 May 1962, was for $1,380,388.00. During negotiations on 9 May 1962, the Contractor agreed to accept $430,000.00 as full and final settlement.

Modification No. 242 is being issued to provide reimbursement to the Contractor for additional construction required for the propellant loading system. The Contractor's original proposal dated 20 April 1962, was for $509,405.00. During negotiations conducted on 5 May 1962, settlement was reached in the amount of $112,000.00.

Modification No. 243 is being issued to provide for subcontractor, Weber Showcase Company, acceleration and impact. The Contractor's original proposal of 6 April 1962, was for $162,912.00. Negotiations were conducted on 17 April 1962, with no agreement reached. On 26 April 1962, during the hearing held by the Contracting Officer, the Contractor was advised that the Government would offer $100,000.00. The Contractor accepted this offer on 27 April 1962.

Modification No. 260 was issued for $9,845,000.00 on 25 May, 1962, to provide reimbursement to the Contractor for acceleration and impact for the prime contractor and for the following subcontractors: Otis Elevator Company, Boise Cascade, Haas, Inc., Gilmore-Skoubye, Century Metal Co., Wells Cargo, Inc., Neri, Inc., Montefusco, B & B Engineering, Johnson Service Co., Alliance Mechanical Contractors, and

Grafe-Weeks Corporation. The Contractor's original proposal amounted to $21,068,352.00. Negotiations were conducted during the period 15 - 22 May 1962, with settlement reached on separable portions on 22 May 1962, in the amount of $6,145,000.00. The remaining amount of $3,700,000 represents unilateral settlement of the Alliance Mechanical Contractor's and Grafe-Weeks Corporation portion.

Other construction contracts for on-base support facilities were:

Invitation No. ENG-45-164-61-8, Contract No. DA-45-164-ENG-3621, Rehabilitation and Air Conditioning of Buildings. The contract was advertised and awarded for the purpose of providing on-base office space for the SATAF organization. Invitation for bid was issued 20 September 1960, with bid opening on 4 October 1960. Five bids were submitted ranging from $43,867.00 to $53,843.00. The Government estimate was $54,010.00. J. E. Nonemacher Construction Company of Boise Idaho, was the low and successful bidder. Notice to Proceed was issued on 11 October 1960. Four modifications to the contract were issued for a final amount of $44,656.70. Contract work was completed within the scheduled contract completion date of 4 April 1961. See Appendix No. 15 for the tabulation of bids and Appendix No. 21 for a tabulation of modifications.

Invitation No. ENG-45-164-61-5, Contract No. DA-45-164-ENG-3623, 25-Ton Liquid Oxygen Plant and Helium Unloading Facility. Invitation for bid was issued 2 September 1960, with bid opening on 19 October 1960. Eight bids were submitted ranging from $402,500.00 to $465,000.00. The Government estimate was $453,527.00. Herrick

Measurements taken at the time the struts were removed and after completion of the backfill indicated no deformation at any stage of the work except for a slight deformation of the tunnel adjacent to tunnel junction No. 10 at Site A. Actually, a good percentage of the 1% strutted deformation remained after complete backfill and there were no sheared bolts or pipe supports or cracking of the cement walkway. These results were due to thorough compaction of the backfill under and adjacent to the tunnel and all subsequent lifts as backfill progressed.

The 9-1/2 foot nominal diameter, corrugated steel multi-plate "A" tunnel sections were fabricated complete with pipe supports into the varying lengths at the Denver, Colorado, plant, shipped by rail to the Boise Plant, and subsequently trucked to the sites. The exterior surfaces of these tunnels were shop coated with 1/8 inch asbestos fibre asphalt mastic prior to shipment. All handling damage to this coating was repaired after the tunnel sections were in place.

The "A" Tunnels were positioned and bolted together without problems and no settlement, damage, or unreasonable deflection was noted after backfill. Since experience with the "B" tunnels had proved that careful and thorough compaction to a point at least 10 feet above the crown would prevent deflection, no struts were used in the "A" Tunnels during backfill operations.

The major portion of the tunnel junction fabrication work was accomplished at the Eaton Metals Company, Salt Lake City, plant with final fabrication and assembly of the tunnel junctions made at the Boise plant. The completed tunnel junctions were trucked from Boise to the sites in one piece, except tunnel junction No. 10, which was delivered in two sections. The Boise Yard welded the cone sections to all tunnel junctions, installed the floor plates, and painted the interior and exterior surfaces.

Close visual inspection was made of all welding with 100% X-ray inspection of yoke and ring beam welds. Adherence to this practice and assurance that the initial backfill was thoroughly compacted provided an uneventful installation with no settling, deflection, or structural failures. Struts were not used during backfill.

Shock Mounting. All areas of the complex are divided into shock zones, as follows:

A Zones - Areas in direct contact with the ground, such as tunnel walls, floors, and domes.

B Zones - Areas isolated by ring footings and sand fill, such as the ground floors of the control center and powerhouse.

C Zones - Area shock mounted on spring beams and coil springs.

Installed equipment was certified as being designed to withstand dynamic (shock) loading of 50 G's, 19 G's, and 3 G's, respectively, for shock zones A, B, and C. Contractor was allowed to install equipment prior to receipt of shock certification in order to expedite progress.

Allowance for movement under shock conditions was accomplished by providing rattle space where such movement was anticipated. Structural joints were closed by neoprene connections. Piping and conduit crossing from one structure to an adjacent structure and from one shock zone to another was isolated by means of flexible connections such as flexible hoses and expansion joints. Numerous problems with respect to the ability of the facilities to withstand movement under shock conditions developed. Upon completion of construction, the final installation continued many deficiencies with respect to hardness; some of these were:

a. Lack of rattle space due to space limitations.

b. Inability of rubber pipe mounts to withstand forces introduced during installation or by hydrostatic pressure.

c. Failure of contract plans and specifications to provide adequate flexible connections.

Following turnover, a team composed of representatives of SATAF, the designer, and the follow-on contractor was scheduled to go through the installation correcting these design deficiencies.

<u>Mechanical Other Than PLS</u>. The mechanical work was subcontracted to Grafe-Weeks and consisted of the installation of various pieces of mechanical equipment and the associated piping, controls, and related items to provide various services and utilities to the entire complex.

A resume of the mechanical systems with their component parts and functions follows:

a. Diesel Engines.

Four diesel-electric units in each powerhouse, each with 100-kw., 60-cycle, 1380/2400-volt rating, provide power and heat to the complexes. These are heavy-duty power plants operating on 2-D and 4-D grade fuels. The units are vapor-phase cooled.

Auxiliary and associated equipment includes:

Cyclonic Separator
Turbocharger Intercooler
Supercharger
Fuel System
Lubrication system
Governor

Intake Air Silencer
Heat Recovery Silencer
Starting Air System
Electrical Equipment
Miscellaneous Items, such as pumps, controls, access doors, catwalks, etc.

b. Cooling Systems

Designed to provide cooling water to all facilities for air conditioning and equipment cooling needs.

Principal equipment consists of:

Heat Recovery Silencers
Cyclonic Separators
Water Chillers, 150-ton each unit, 2 units in Powerhouse
Ice Banks, 15-tons ice each unit, 2 units in Powerhouse
Cooling Towers, 830 GPM each unit, 2 units in Powerhouse
Cooling Towers, 125 GPM each unit, 1 unit in Powerhouse for cooling deep-well water which arrives at temperatures of up to 175° F.

c. Heating System.

The heat source is waste heat from the diesel engine water jackets and exhaust gases. Heat is supplied to intake air, lube oil and fuel oil for the diesel engines and to the heating water for the air conditioning system, domestic water service, and ice prevention system.

Principal equipment consists of:

Cyclonic Separators, 1 per engine to produce 30 psig steam
Heat recovery silencers, 1 per engine to produce 8 psig steam
Heat Exchangers, 7 per Powerhouse, hot water, ethylene glycol, control-air aftercooler, fuel oil, caustic supply, and domestic hot water
Hot-water heating coil, 14300 cfm in the air filtration facility
Unit heaters, 1205 cfm, 2 units in Propellant Terminal

Two Heat Exchangers, 8.2 GPM, in antenna silo pumps, controls, etc.

d. Water Systems.

These provide complete water distribution system to all facilities and include:

Domestic Hot and Cold Water System
Cooling Water System
Steam and Condensate System
Firing Water
Water Treatment system
Seepage Waste
Sanitary Sewers
Contaminated and Sewage Waste

Major equipment includes:

Pumps, Motors, Controls, etc.
Piping Lines, Supports, Shock Mounts, Fixtures and Devices
Valves, Flexible Hoses, Rupture Discs, Pressure and Temperature Controllers and Indicators
Tanks
Water Treatment Plant

Of special interest is the water treatment plant which is a completely automatic water demineralization and treatment plant consisting of:

1 Dual, 2-Bed Demineralizing plant
2 Cation and 2 Anion Exchangers
Cooling Towers
Caustic Handling, Storage and Admixing Facilities
Acid Storage, Handling and Admixing Facilities
Piping, Valves, Interlocks, Alarms, Meters, Etc.

e. Air Conditioning.

Provides air conditioning to all facilities, except the powerhouse, completely automatic and with heat, cooling, filtering, ventilating and humidity control.

Major equipment includes:

1 Air conditioning unit in propellant terminal, 875 cfm
6 Air conditioning units in equipment terminal, 20,375 cfm combined peak load capacity
3 Air conditioning units in control center, 17,900 cfm combined peak load capacity
3 Air conditioning units in antenna terminal, 6,290 cfm combined peak load capacity

f. Ventilation System.

Designed to provide fresh air in all facilities and to remove stale air. This air is filtered and washed as it enters the air-filtration facility.

Major equipment consists of:

Hot-Water Tempering coils in air filtration facility, 14,300 cfm
Spray Humidifiers in air filtration facility, 240,000 cfm
Dust Collector in air filtration facility, 34,300 cfm

Fans:
- 1 Exhaust Facility, 222,500 cfm
- 1 Air Filtration Facility, 240,000 cfm
- 1 Exhaust Air, 875 cfm, Propellant Terminal
- 1 Tunnel Ventilation, 3,900 cfm, Propellant Terminal
- 3 Exhaust and recirculation, 10,650 cfm, Equipment Terminal
- 4 Exhaust and Recirculation, 14,300 cfm, Control Center
- 1 Launcher Area Filtration, 26,625 cfm

g. Air Systems.

These provide compressed air for starting the diesel engines, utility air throughout the facility, and control air for various valves and control devices.

Major equipment includes:

1 Compressor, starting air, 325 cfm in Powerhouse
1 Compressor, utility air, 555 cfm, in Powerhouse
1 Compressor, plant air, 1005 cfm, in each Equipment Terminal

Several small control air compressors in various locations

h. Fuel Systems.

These provide storage and handling facilities for lubricating and fuel oils for the diesel engines. Major pieces of equipment include tanks, pumps, centrifuge, heat exchangers, and associated piping.

i. Special Devices.

These include blast locks, blast doors, blast valves, elevators, and cranes.

The blast system consists of an elaborate arrangement of hydraulically and pneumatically operated locks, valves, and doors designed to protect the complex from both external blast damage and internal damage due to misfire. The doors and locks are located to isolate each launcher from the other areas of the complex. The valves are automatically operated and provide air to the complex by bypassing the blast locks.

There are elevators in each equipment terminal, portal silo, and antenna silo. These are used to move passengers and freight in and out of the complex. Missile silo elevators are installed by the I & C contractors.

There is a radial bridge-crane in the powerhouse designed for a 10-ton maximum load.

j. Miscellaneous.

Miscellaneous equipment consists of food handling equipment, fire protection system, sump anddrain pumps, and associated piping.

Installation of the mechanical work began in late 1960 and was basically completed at all sites by December 1961. During the early states of construction, much foresight and preparation had to be done to prepare for the bulk of the installation. Pipe sleeves had to be located and placed; embedded pipes, anchors, and hangar supports had to be installed during the time the structural work was being done; large items of mechanical equipment, such as the engine-generators and water chillers, had to be brought into the powerhouse before it was finally enclosed.

As installation of equipment and associated items progressed, problems of various types began to appear. Some of the major ones and their solution were as follows:

a. The water well packer at Site B was most difficult to set and repeated attempts resulted in failure. After modifying the packer to some extent and improving the method of setting, the packer was finally installed successfully.

b. The C-2 compressors located in the equipment terminals had excessive vibration when installed as specified. The shock mountings were then modified and the vibration was considerably reduced.

c. The condensing water pumps were installed above the level of the water in the cooling towers, and the pumps, therefore, lost their prime. It was necessary to lower the pumps in order to make the system workable.

d. The cooling towers on the mezzanine floor in the powerhouse at Sites B and C created steam when the hot water from the wells flowed through them. The steam would condense on the ceiling and equipment and cause damage to the paint and mechanical and electrical equipment. Problem has been corrected to some degree by ducting the air discharge from the tower into the exhaust structure; however, this has created problems there since the moisture combines with the sulphur discharged from the engine-generators and forms sulphuric acid which attacks the blast valves and other components in the structure.

e. The pipe supports in the tunnels were found inadequate and required redesigning and replacing. This delayed the installation and testing of the mechanical equipment.

Testing of the mechanical equipment was a major undertaking. Acceptance testing, as required by the construction contract, was done at Sites B and C. Validation testing was done at Site A. Acceptance testing was done at Site A in those areas where validation testing did not apply. The testing began at Site C in June 1961, and was completed at all sites by the first of April 1962. Testing was conducted simultaneously on all three sites.

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The testing program progressed smoothly; this can be largely attributed to the fact that the Corps of Engineers was prepared by having test procedures carefully studied and thoroughly planned before testing began. The test of diesel engine-generators was perhaps the most vital and complicated test. This was performed at all three sites with practically no difficulties.

Electrical Work. During the concrete operations, the electrical subcontractor's work consisted of installing ground mats under the

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foundations of the powerhouse, control center, missile silos, equipment terminals propellant terminals, and antenna silos, and the installation of the grounding cables, grounding plates, junction boxes, and rigid conduits in the forms prior to the placement of the concrete. As the concrete placement s were completed for the various structures, conduit installations were made. In some cases, the conduit was installed prior to other work without sufficient coordination between the various trades. As a result, several installations had to be removed and relocated to permit the installation of other equipment.

Complex C was the lead site and, as a result, first encountered most of the design and installation problems. Solutions to these problems encountered at Complex C greatly benefited the other two sites. Examples of such problems are:

a. The contract drawings did not provide for lighting contractors for the "A" and "B" tunnel lighting systems fed from the control center. This was a design deficiency and was resolved by issuing a modification requiring the installation.

b. The supports for the conduits in the tunnels could not be attached to the tunnel inserts using regular unistrut conduit clamps or straps unless numerous offsets or bends were made in the conduits to avoid interferences with bolts, flanges, etc. This was an installation problem and was resolved when the Contractor used a type of conduit clamp that provided sufficient clearance between the tunnel wall and conduit so that the flanges, bolts, etc., did not interfere. This method facilitated conduit installations throughout the tunnels.

The electrical subcontractor was responsible for installation of the following systems and/or equipment:

a. Diesel-generator System

b. 2.4KV Switchgear

c. Unit Substations

d. Motor Control Centers

e. Panelboards

f. Lighting Transformers

g. Normal Lighting Systems

h. Emergency Lighting Systems

i. Control Battery Systems

j. Cable Tray Systems

k. Closed Circuit Television System

l. Signal and Alarm Systems

(1) Gas Detection

(2) Fire Detection

(3) Radiation Detection

(4) Explosion Detection

(5) Wind Detection

m. PLS Control Wiring

The electrical subcontractor was also responsible for procurement of the above equipment with the exception of that furnished as standardized equipment. This equipment consisted of the following:

a. Diesel-engine Generators

b. 2.4KV Switchgear

c. Signal and Alarm Systems

(1) Gas Detectors

(2) Fire Detectors

(3) Radiation Detectors

(4) Anemometers

Electrical testing at Complexes B and C consisted of acceptance testing as required by the original contract. At Complex A, validation testing was performed as added by modification. On systems which were not tested under the validation testing program, acceptance tests were conducted.

Propellant Loading System. The principal function of the propellant loading system is to store and, upon command, to automatically load liquid oxygen and helium aboard the missile. The liquid oxygen (LOX) is transferred by pressurizing the LOX storage vessel with gaseous nitrogen, thus forcing the liquid into the missile. The helium, stored in the propellant terminal at 6000 psig, is transferred through regulating valves to the missile; final loading helium is allowed to flow through coils submerged in liquid nitrogen. This cools the helium to approximately -300° F. to permit a greater volume storage on board. The final LOX loading, called the "LOX Topping," is also passed through coils submerged in liquid nitrogen, thus subcooling the LOX and minimizing boil-off immediately prior to firing.

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The RP-1 portion of the propellant loadingsystem is a semi-automatic system and, unlike the helium and LOX systems which are rapid load type, the RP-1 is pumped from a storage vessel to each of the missiles during standby status.

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Although the many propellant loading systems are similar in appearance to any complex process piping system, the distinguishing feature of these systems is the interior cleanliness requirement of each completed piping installation. The limit of allowable contamination of the RP-1 system is a particle 150 microns in size. This is equal to 0.00587 inches or the approximate size of a dot made by a well sharpened pencil. The same limit of maximum allowable particle size applies to the LOX, helium, and gaseous nitrogen systems plus the additional cleanliness requirement of hydrocarbon contamination reduced to less than 72 parts per million as taken in a gas analysis.

To insure these cleanliness requirements, elaborate precautions were implemented throughout the cleaning, storage, installation, and testing phases of PLS systems. The rooms in the Contractor's cleaning plant where final rinsing, inspection, and sealing took place were kept in a surgically clean status with a well filtered air-conditioning system designed to maintain a positive pressure within the rooms to insure the clean state. In the field, workmen wore nylon smocks and polyethylene gloves while handling and installing piping components. After system installations were completed, extensive testing procedures were conducted to insure the propriety of each system.

The first PLS activity was the arrival of standardized equipment. These items were furnished under Corps of Engineers' supply contracts. These contracts were assigned to the Prime Contractor. This standardized equipment included such parts as cryogenic vessels, liquid storage vessels for the RP-1 fuel, high pressure gaseous storage vessels, flow control valves, the standard bar stock valves, and all the control components known as the control system instrumentation package. The first items of standardized equipment arrived in this area in the late summer of 1960. These were the RP-1 storage vessels, 30,000 gallon capacity. Following these items were the gaseous nitrogen storage vessels, Keenan Pipe & Supply Company (See Plate 32, Figs. I & II); these came in throughout the fall of 1960 along with the cryogenic vessels which included the LOX storage vessel T-201, a 28,000 gallon vacuum dewar; the LOX subcooler T-201, a 15,000 gallon vacuum dewar w/heat exchanger coils; and the helium cooler T-204, a 1,050 gallon vacuum dewar w/heat exchanger coils. Included in this delivery from LOX Equipment Company were the catch pots. The automatic flow control valves supplied through the CompuDyne contract were Kieley-Mueller manufactured. These and the Powell valves, the majority of which were bar stock material, began to arrive in the fall of 1960; the conclusion of this shipment was sometime in the spring of 1961. The first notice of difficulty with these supplied items was that some of the cryogenic vessels were losing their internal blanket pressurization as well as the vacuum in the annular space. Also the gaseous storage vessels were losing their blanket pressurization. This was soon remedied by the Contractor making a survey, at the Government's request, to determine which of the vessels were losing either their internal blanket pressurization or the vacuum of their annular space, and resolving the situation accordingly. Since the high pressure vessels (gaseous storage vessels) were of a simple structure, it was rather easy to determine where the leaks were and take the necessary action. However, in the case of the cryogenic vessels, a different situation was involved. The annular space, an evacuated area, was of a more complex nature and it entailed a rather detailed and exacting study to determine the exact cause of the malfunction, and the repair was necessarily made by a vacuum repair specialist.

The installation of the T-201 LOX vessels imposed an interesting problem during the construction stage. It was first thought that it would be necessary to utilize cranes to lower these 85,000 pound items onto their pads. Since the LOX bay was located in an area of the open-cut excavation which limited the access surrounding it, it could not be determined how cranes could lift the vessels from some accessible location without hampering their own operation. The problem was soon solved when a subcontract was let for this particular operation. The subcontractor was regularly engaged in house moving and, to him, the vessels did not appear to pose any problem at all. A small earth fill was developed between one of the ramps and the LOX bay floor, then the vessels were backed across the fill and directly onto the bay floor. Through use of multiple hydro-pneumatic jacks operated from one truck mounted pneumatic source, the moving tractor and dollies were quickly removed from beneath the vessel and it was nestled onto cribing within one-inch of its final suspended position. (See Figs. I and II on Plates 25 through 28.)

The next significant event was that of the initial fabrication of propellant loading system piping. All the pipe for the propellant loading system was prefabricated in spool sections in the Grafe-Weeks fabrication plant in Boise (See Fig. II, Plat 37), after fabrication, it was processed through the cleaning plant located in the same area. It was in this cleaning plant that surgically clean conditions existed. The completed sealed items for the propellant loading system were stored in the LOX-clean room of the cleaning plant prior to being shipped to the site (See Figs. I & II, Plate 38.) After installation of the cryogenic and gaseous storage vessels for one terminal was completed, the installation of the propellant loading system piping was initiated. The first date of installation was 1 May 1961. This was started at propellant terminal No. 2 at Complex C. All of the terminals of the three complexes followed thereafter (See Plates 33, 34 and 35.) The missile silo at each launcher comprises the other half of the PLS piping system area. Within this silo are two large structural frames called the LOX crib and the Fuel Crib. These items are bridge-like structures which stand vertically (See Fig. II, Plate 29.) Within the LOX cribs is the prefabricated piping for the terminal end of the liquid oxygen, helium, and nitrogen systems. The RP-1 stage loading platforms are contained in the fuel crib. After the structural members of each of the cribs were fabricated, they were inclosed in a polyethylene type balloon building which was pressurized to maintain cleanliness and structural stability. Within each of these tents, the propellant loading system piping was installed in the cribs (See Figs. I & II, Plate 36, and Fig. I, Plate 37.) This was a prefabricated type unit that, when completed, was hauled to the site in one piece and lowered into the silo (See Fig. I, Plate 29.) The interconnecting piping from the missile silo to those systems within the propellant terminal was then completed. The first terminal piping installation was completed on approximately 1 October 1961, and the system testing began shortly thereafter.

The system tests consist of proof pressurizing each individual system to 125% of its maximum working pressure to test its capability to withstanding surges and overloads. After this test the pressure is reduced to the working pressure and a leak check is made. During the proof pressure testing, no one is allowed within the pipe inclosure. The leak test is conducted by soaping each joint and fixture with an item similar to that of Leak Tek or Sherlock type lead detecting liquids. After the successful completion of the leak test, the system is prepared for blowdowns. It is this blowdown sequence that proves the cleanliness of the system. A certain minor portion of cleaning is accomplished with this blowdown wherein the minor amount of contamination that is induced during the installation phase is removed by the rapid flow of the gases through the pipe. This cleanliness is proved by taking pad samples which consist of multiple layers of gauze placed in the open end of the pipe through which the gas is exhausted and analyzing them microscopically for particle size. The hydrocarbon content is then analyzed by capturing a sample of the gas in a small pressure bottle and analyzing it through by means of a gas analyzer known as the Perkins-Elmer Analyzer. During the installation phase of the PLS system, each of the system safety valves was taken to a bench test laboratory where it was tested and reset for the pressure setting required by the design. After the successful completion of one terminal's system tests, the safety valves were installed, replacing a capped outlet in the piping. At this time, a revalidation was conducted on each individual system. This included the pressurization of the lines back to working pressure and leak checking any connections or openings which had to be retightened or realigned. Following the revalidation, each individual system was placed in a standby condition which consisted of maintaining a blanket pressuriation of from 2 to 7 pounds pressure of gaseous nitrogen throughout.

Concurrent with the system testing was the control system testing. This is a separate phase of testing on the propellant loading system which was conducted by another independent contractor involved primarily in this work. It involved the calibration of each of the system control components to insure its proper operation after being installed in the field. After each individual piping system and each control component were satisfactorily tested and calibrated, the tests were signed off by members of the Corps of Engineers, the testing contractor, representatives from the Martin Company, and the Air Force SATAF personnel. When this was all accomplished and the records were forwarded to the proper authorities, a terminal and missile propellant loading system was considered complete.

The RP-1 system was handled separately, but similar tests were made. Although blowdowns were only made on a gaseous nitrogen portion of the system, the RP-1 piping itself was flushed through a circulation process which involved a fuel tanker capable of filtering the fuel and recirculating it throughout the system. The average length of time for each individual flushing operation was two hours. After a satisfactory clean sample was received from each flushing operation, the system was pumped down and a blanket pressurization of gaseous nitrogen placed on each line. The subsequent signing off of certificates of tests was similar to that of the propellant system which involved the LOX, helium and gaseous nitrogen systems. After completion of each test and validation, the systems were maintained in a standby status by the installing contractor until the structures were transferred to the using agency.

The major operational problem encountered in the propellant loading system activities was that of the lack of coordination between the various subcontractors involved in the installation, testing, validating and calibrating of this system. Although at many other Titan I facilities the prime contract venture involved a mechanical contractor who took over the propellant loading system, in this area the mechanical work was entirely subcontracted to the Grafe-Weeks Corporation who, in turn, subcontracted the propellant loading system testing to Tidmarsh Ventures, Inc. They, in turn, subcontracted the control system testing to CompuDyne Corporation. This imposed many problems in coordination. Although the prime contractor employed coordinators at each site as did the subcontractor, Grafe-Weeks, they seemed unable to prevent difficulties involving delays caused by the division of work. The principal problem concerned who had responsibility for a particular portion of the work. The people in the field were not familiar with the actual contractual relationships between one company and another and, therefore, consuming delays were encountered. The main solution to this problem was to have the Government representatives take the responsibility of coordinating the work of the various contractors by establishing progress procedures and pointing out the deficiencies and anticipated delays that were unforeseen by the various contractors. This was reinforced by numerous progress meetings held at the Area level between representatives of the Contractors and Corps of Engineers.

Another major difficulty was that of the standardized equipment. Under the conditions of the assignment of contractors, the prime Contractor refused to take complete responsibility for the standardized equipment wherein he recognized this equipment as being Government-furnished property and would not take the initiative to resolve any deficiencies noted in the equipment or difficulties involved in the operational capabilities of each of the supplied items. Although many of the problems involving the cryogenic vessels and the vacuum of their annular space were solved during the period of February through April 1961, these same difficulties became apparent at the time of testing; that is, in October 1961. This was caused mainly by the lack of knowledge of proper care of these vessels and often the small thermocouple type tube which was exposed on the exterior of the vessel became ruptured and the vessels vacuum lost. This was resolved by assigning one Corps of Engineer's man solely to this problem whose primary purpose was to coordinate the efforts of the Contractor in resolving the difficulties of each particular vessel. This operation lasted throughout the final testing phases of the propellant loading system. The standardized equipment valves also posed a problem wherein many of the valves showed seat leakage and deficiencies throughout the automatic operators. It was not until directies were issued by the Government that the Contractor took any action to repair the difficulties. This operation also was solved by individual assignment of Government personnel to oversee the successful completion of the deficiencies noted.

Progress Data. Contractor's original progress schedule (See Appendix No. 11) called for maximum production during the period February through May 1961, with an abrupt lessening of the rate of production immediately following this period. A curve based on Contractor's dollar earnings (See Appendix No. 12) shows that progress did, in general, follow this schedule for the original contract value; however, because of modifications and changes involved, Contractor was unable to reduce his construction effort following May 1961, but, rather, was forced to continue a maximum effort in order to complete the work by 1 April 1962. As a matter of fact, the tabulation of work force contained in Appendix No. 13 indicates he reached his peak work force during the months of September and October 1961. By 31 March 1962, his on-site work force had been reduced to 28.

Acceleration. There were many directed additions to Contractor's work that had to be encompassed largely within his original time frame. These had the normal effects of acceleration upon his costs.

a. Lack of labor efficiency due to work hours in excess of 48 hours per week, over-running of work areas, lack of efficient supervision, disinclination to weed out inefficient personnel during periods of build-up, inability to maintain an efficient ration between required skills.

b. Contractor found it necessary to increase his over-all plant capacity.

c. Continued disruption of production schedules and project planning.

d. Required skills were in short supply and successful recruitment required large expenditures for overtime and other inducements. This was particularly true in electrical and mechanical fields where Contractor had to entice men from as far away as Texas.

e. Methods of construction were intruduced which were fast but often not economical.

f. Contractor was unable to take advantage of a "learning curve" through repetitious use of crews throughout the facilities.

The fact that work was completed by the original scheduled completion date indicates that the Contractor did take sufficient measures to accelerate the work; however, these measures resulted in substantial increases in his costs. As of the end of May 1962, a single modification was processed which reimbursed him in the amount of $9,845,000 and there were indications that further reimbursement might be justified. There also were payments for acceleration factors incorporated in other modifications.

<u>Liquidated Damages.</u> By Supplement No. 4 to Modification No. 92, additional time for the various structures was granted the Contractor;

however, this did not entirely wipe out the liquidated damages being withheld and, as of the end of May 1962, the sum of $42,300 in liquidated damages was still being withheld. It should be noted that no individual structure in any complex required time for construction beyond the original completion date for that complex.

Labor Relations. The availability of labor constituted one of the major problems at Mountain Home. Many factors combined to make this area one of the least attractive in the nation for the skilled trades. Most important to be considered under this heading are the wage rates. Of the missile sites, including Beale, Lowry, Vandenburg, Larson, Wichita, Ellsworth, Tucson, and Mountain Home, the two bases which had the lowest wage rates for pipefitters, welders, and electricians were Mountain Home and Ellsworth.

The trades mentioned above were critical for this type of construction and the workers were generally a mobile group which tended to flow toward higher rates and sunnier climes. It was obvious that Mountain Home was in a poor competitive position to attract workers. Pressure was, of course, exerted by local permanent industries not to increase these rates. In addition, the enrollment in the Locals was small compared to current demand and most of the local lmembers prefer long time jobs involving a minimum of travel.

Tremendous efforts were exerted by the local business agents to man these jobs. The statistics quoted by Clayton W. Bilderback, of the United Association of Journeymen Plumbers and Pipefitters, in his letter of 1 September 1961 to Grafe-Weeks Corporation show that the

Unions made a serious effort to comply with the demands of the Contractors but were not able to meet the requirements.

The best description of the relationship between contractors and labor might be a statement that there was a spirit of practical compromise and mutual respect. While the Contractor did not have a 100% strike-free construction period, the experience in work stoppages at this base compared more than favorably with other Titan I installations. No strikes were called and the union officials exerted sincere efforts to reduce the impact and unauthorized walk-outs. Their efforts were not completely effective, but this may have been due to the transient nature of the labor pool and to the fact that the conditions were unusual. The pipefitters and welders had to operate under the "surgically clean" methods which increase the problems normally found in construction work. The underground operations with consequent ventilation problems and the heat of the desert in above-ground activities contributed to the difficulty in keeping men on the job and in detracting from their efficiency. On the whole, it may be said that the relationships between the contractors and labor were as good as could be expected considering the type of job being done.