9. SURFACE STABILIZATION

General:

As a measure to prevent erosion of the fine, silty topsoil encountered in the area of the complexes, all areas except paved areas, scarred or denuded in the course of construction operations and lying within the security fence were covered to a depth of 3 inches with an open-graded gravel 3/4 inch to 2 inches in size, with a preponderence of 1-1/2 and 2 inch sizes. The original bid under item No. 21, Soil Stabilization, was 46.6 acres total for all three complexes. However, due to the requirement for coverage of additional areas within the complexes, a total area of 90.6 acres required soil stabilization treatment. Total end cost for this item was $119,525.

Complex 1-A:

Soil stabilization operations started on 26 June 1961 by S&S Sand and Gravel Company, Ephrata, Washington. The gradation was checked and cleared by the Larson Area Office Laboratory. The rock was crushed and screened at a basalt quarry approximately 4 miles southwest of the complex.

Bottom dump semi-trucks were used for hauling and spreading the rock. The gates were set to spread the required blanket thickness. This was an excellent method and a smooth spread was obtained in the larger straightaway areas. Where curves and structures were involved, the rock was spread as well as possible but some blading and hand-work was required around structures to maintain required blanket thickness.

During the early part of soil-stabilization operations the Contractor worked one shift. However, as more area was graded and made available he went on two 8-hour shifts. The day shift started at 0400 hours to take advantage of the daylight hours.

Soil stabilization was completed 24 July 1961 except for stockpiling for areas occupied by offices and buildings. Rock for these areas was stockpiled to be placed by others except for the areas occupied by the Construction Contractor and the Corps of Engineer Offices.

The stabilization operation proceeded normally and smoothly. Some short delays were encountered due to mechanical breakdowns on the crusher. The operation on the whole was well organized and supervised.

Complex 1-B:

A crushing and screening plant was set up on site by the S&S Sand and Gravel Company of Ephrata, Washington. Material located on site was crushed and screened for use on this site. The gradation of the finished product was closely checked by the field laboratory personnel. No difficulty was encountered in the production phase of this operation. In open areas the trucks were used to haul and spread this material to the required blanket thickness. In confined areas the material was spread and graded using hand tools.

Sufficient stabilization material for the areas occupied by the Associate Contractor's buildings was stockpiled in an area near the southwest corner of the complex. The material is to be placed by the respective associate contractor. Material was stockpiled in the vicinity of contractor-owned buildings to be placed by him on the removal of the buildings.

The crushing and screening plant set up by S&S Sand and Gravel Company was used to produce all aggregates used in the roads and the soil stabilization. The final work of placing stabilization material on the road shoulders was completed 22 September 1961.

Complex 1-C:

The S&S Sand and Gravel Company set up a portable crushing and screening plant at the complex on 12 September 1961. Placement operations started on 15 September 1961 and were completed by 10 October 1961. The material was checked for compliance with the specifications by Larson Area personnel. No difficulty was experienced in the processing of the material. All material except that used for the concrete aggregate and asphalt roads was produced on site. The Contractor was directed to provide for stockpiling sufficient stabilization material to cover the 132,000 sq. ft. of areas occupied by buildings used by the Associate Contractors.

The method of placement was the same as that used at Complex 1-A and Complex 1-B. Some difficulty was experienced in getting the Contractor to thoroughly cover stabilized areas. It was necessary to make numerous inspections with the S&S supervisor before all bare spots were covered.

10. PROPELLANT LOADING SYSTEM

Purpose:

The purpose of the TITAN I Propellant Loading System is to store and transfer into the missile body those gases and cryogenic fluids necessary for the launching of the TITAN I missile. The gases are helium and gaseous nitrogen and the cryogenic liquid is liquid oxygen. The equipment is all located in underground facilities and a separate Propellant Loading System is provided for each launcher. The PLS is capable of loading the missile within the time allowed by the countdown. The actual loading must be such that sufficient time is allowed for subsequent operations to be performed.

The PLS has the highest possible inherent reliability and is maintained in a continuous state of readiness, except for periods of resupply and maintenance. The PLS is capable of a 10-day isolation period without recourse to outside supplies. In the normal schedule, the intervals between resupply may be as long as 10 days. Therefore, the PLS is designed so that its full capacity is maintained throughout a 20-day interval without recourse to outside supplies.

The PLS has the capacity to load the missile, hold it in a loaded condition for one hour, unload and reload. Compressed gas is used to transfer liquid oxygen from storage to the missile. The gas used is nitrogen. Loading is automatic and is initiated from a remote location. The PLS incorporates piping and valves for the recovery of helium. The system stores and maintains sufficient quantities of propellants and gases to insure the performance as outlined above.

PLS Cleanliness:

Due to the nature of the TITAN I missile engine and the shock sensitivity of liquid oxygen when combined with hydrocarbon compounds, it becomes extremely important to set and meet criteria for certain cleanliness standards. This includes total solid contamination with upper limit of 75 parts per million, 72 parts per million hydrocarbon, and an upper limit of two parts per million acetylene. In order to produce components in the system which meet these cleanliness criteria, it was necessary for the prime construction contractor to establish and operate clean room facilities which are highly specialized and require many hours of tedious production time in order to clean the part properly. This includes all components which come in contact with gases or cryogenic liquids which eventually find their way into the missile engine.

During this project, MacDonald-Scott & Associates engaged two subcontractors to operate cleaning facilities. One was the Dow Chemical Co., which maintained a large cleaning plant at Warden, Washington, and which accomplished the majority of cleaning. This included mainly, spool pieces and other items as required on a "crash-basis" when time was of the essence.

The other cleaning facility was operated by the standardized equipment supplier, CompuDyne Corporation. The bulk of their cleaning included field cleaning of the standardized equipment valves and included safety valves, flow control valves and solenoid-operated valves. Some filters and filter bodies were also cleaned at the CompuDyne Corporation shop.

Composition of the PLS:

At the heart of the Propellant Loading System are the cryogenic vessels. These are large vacuum insulated vessels which contain the LOX oxidizer and the two smaller sub-coolers which serve as heat exchangers in cooling down the liquid oxygen for topping and the gaseous helium for in-flight pressurization of the missile oxidizer tanks.

In order to transfer the liquid oxygen from the storage tank into the missile body, the tank and lines must be pressurized. This is done with gaseous nitrogen which is stored in large high-pressure bottle banks in the Propellant Terminal. Similar high-pressure bottles are used to store the gaseous helium. A vast network of high and low-pressure stainless steel lines connects these bottles through valving systems to the cryogenic tanks. There is also a supply of nitrogen gas to operate various disconnect lines which terminate in the Missile Silo, and connect through umbilical cords to the missile launch platform umbilical tower. Flow-control valves, automatic-control valves, solenoid-operated valves and hand valves all go to make up the complete valving network.

When the Propellant Loading System is complete and ready for operation, it may be actuated from the Control Center by electrical means to slave units in the Equipment Terminal which transmit this signal through cables into the Propellant Terminal. There is a separate control panel containing pressure switches and pressure controllers for the helium, oxygen and nitrogen systems. These are all located in-bank in the center of the Propellant Terminal on a raised platform.

It is interesting to note that a good deal of the equipment was standardized by the Government and purchased from specific manufacturers so as to maintain uniformity throughout the program. Some of the major items of standardized equipment are the cryogenic vessels, the valves, the control panels and the servo-mechanisms which constitute the control systems. Standardization of the equipment will allow a more rapid resupply of spare parts and a reduction in the number of on-shelf items for support during the I&C and operational phases of the project.

Major Problem Areas and Solutions:

The following is a brief discussion of some of the major problem areas encountered by the PLS staff personnel during the construction and installation phase and the testing program.

Improper Storage and Handling was the first problem this PLS section had to deal with. The prime contractor, having never experienced this type of construction project, was not aware of the dire necessity for proper storage and handling of PLS components after the time they had been factory-cleaned and prior to integration into the system. Many steps had to be observed to assure proper care.

After LOX cleaning of an item at the factory or cleaning facility, careful inspection is made in the cleaning plant clean room and while under purge, the open ends or open parts of a component are carefully sealed. During transport from the cleaning facility to the point of installation, the item must be carefully handled so that the plastic covers and tape are not broken allowing an introduction of contaminates into the component. During this project, a great many items were stored out of doors or in wholly unsuitable indoor storage, allowing dirt and moisture to enter the otherwise clean component. Repeated Government inspection, both at cleaning facilities and at points of storage with vigorous follow-up action, rectified this problem to the point where a minimum amount of recleaning was necessary.

With respect to the cleaning of standardized equipment valves, many of these, upon receipt at the Contractor's warehouse in Ephrata, Washington, were being rejected by Corps of Engineers inspectors. Therefore, the prime contractor hired an independent laboratory to make a percentage spot-check of valves received at his plant. These valves were supposed to have been factory LOX cleaned prior to shipment to the prime contractor. The independent laboratory found that of those which he inspected, approximately 90% would not pass the LOX clean criteria. The prime contractor was directed, therefore, to perform 100% LOX cleaning of all these valves in the field. It was at this time that the prime contractor directed their subcontractor, the CompuDyne Corporation, to set up and operate a LOX clean facility in order to clean the valves to specification requirements. All valves were completely disassembled and cleaned at the field plant.

Another major problem was the lack of specification welding on the pre-fabricated spool pieces made by the Scott Co. fabrication shop in Oakland, California. Upon receipt of these spool pieces in the field, CE inspectors found many welds to be faulty. The X-rays which were made at the Oakland fabrication shop were completely inspected by CE inspectors and was determined that many hundreds of the welds had to be field repaired, re-X-rayed and approved prior to final acceptance in system. Procedures were set up between the prime contractor and CE field inspectors by which the individual welds were marked, reworked, inspected, X-rayed and approved and all appropriate records made prior to final acceptance of welds. This was a time-consuming operation lasting about four months.

Purging. A great deal of confusion existed about the contract requirements for providing an inert gaseous backup purge for field welding of stainless steel lines. It was finally decided to give the prime contractor a change order directing that he do this in order to provide quality welds on the first attempt at connection.

A requirement to maintain a clean dry nitrogen purge in the system also existed and was followed with fair results. Actually, all moisture and contamination were removed from the system during specification testing and subsequent to testing the clean dry blanket purge was left on all lines. In the case of cryogenic vessels after testing, either a dry gaseous purge or liquid nitrogen was left in the vessels.

Aminco Fittings. After construction was well underway, it was determined that several of the Aminco fittings were of the wrong specification material and had to be replaced. These were normally found on high-pressure connections and changeout of the fittings required cutting, rewelding new pieces onto the lines, re-X-ray and approval of the X-rays before final acceptance.

Joints. The unusual nature of a cryogenic pipe system requires the use of many joints due to the contraction of stainless steel piping at cryogenic temperatures. These include expansion joints, hinge joints and gimbal joints, all of which serve to allow the system to act as a machine during cold flow.

The installed tolerances of these joints is critical in installation and is a controlling factor in piping installation.

Technical Problems Regarding Installed Joint Dimension. The prime contractor did not realize the critical dimension problem early in the installation and was finally required to place restrainer bars on all joints so as to hold them to installed tolerances. This required respooling of many pipe runs to conform to installed tolerance of the joints. Finally, some of the joints could only be inspected and accepted in the system by blocking or artificially holding them in position and measuring for the proper tolerances. Blocking and artificial supports then were removed and in no case did a joint fail during testing due to structural imperfections or improperly installed tolerance violation.

A re-analysis of stresses in the system was made by the system designer, A. D. Little, Inc. after installation of piping had begun. As a result, many of the supports, anchors and guides were modified or increased prior to the end of the construction phase. The prime contractor worked under an extreme hardship in this instance, since many of the supports had to be hand-fitted after piping had been temporarily installed. A certain amount of tunnel settlement required field fitting and routing of piping and refitting of pipe supports. Slight deviations exist at all three complexes due to differing amounts of differential settlement of tunnel sections.

The liquid oxygen and RP-1 fuel cribs were pre-fabricated at the Warden fabrication shop and all or most of the valves and piping installed in the cribs. At this point, the cribs were lowered as a single unit into the missile silo and set on supports as designed. This was a highly-coordinated activity pursued by the contractor with great vigor and skill and is one of the high points of the PLS and RP-1 installation phase.

Testing:

The object of PLS testing is to prove the structural adequacy, cleanliness, suitability of individual components of the system. It involves a complete proof-pressure and leak check of all lines, a vacuum retention test of cryogenic vessels, and selected evaporation loss tests on the liquid oxygen storage tanks. A complete check and calibration of the control system was also run. During the proof-pressure test, lines are subjected to 1¼ times their working pressure, held for five minutes and checked for structural damage.

During the leak-check a liquid soap or specially concocted fluid is applied to all possible points of leakage and the system bubble-checked for tightness. During the blowdown of the lines, gaseous nitrogen is passed through the line at a certain pressure for a given time or for a certain pressure drop and a special blow horn device is placed on the line end to entrap anything that may come out of the line. These pads are then analyzed for fluorescence and a qualitative analysis is made. Gas samples are also taken to determine whether or not there are hydrocarbon materials in the lines.

In the summer of 1961 it became apparent that the Scott Co. were in danger of falling seriously behind schedule in the PLS testing program. At this time the joint venture, particularly Paul Hardeman, Inc., furnished available experienced personnel to bolster the management and operations staff of the Sponsors. The testing program immediately picked up tempo and at one time six Propellant Terminals were under test. A maximum of about 60 technical inspectors were used during the height of the program. Testing was done on a six-day-a-week basis, two 10-hour shifts per day.

The Contractor's testing team consisted of a test director, a fitter foreman, seven pipefitters, a safety man, a test recorder and the necessary laboratory personnel to analyze the test pads and gases. The Government test team consisted of a test director, assistant test director, a CE inspector assistant and MMC quality control construction surveillance technician.

The contractor and the Government had two teams each day for each Propellant Terminal during testing. The average time for a complete test for each Propellant Terminal was four weeks.

In addition to the teams testing in each Propellant Terminal, the contractor had a large field force consisting of technicians for the operation of rechargers, tube banks and helium compressors, and a good many drivers and fitters charged with the responsibility of delivering and putting the gases and liquids required into the system.

An intricate communication system was set up in each Propellant Terminal, having two telephones which could be reached directly from any point on the complex or from any telephone in the ABC area, CE office. Two CE officer test directors were available 24 hours a day and each had a telephone at his place of business and his quarters for around-the-clock contact with contractor's personnel and test directors.

Government-Furnished Gases and Equipment:

The Government furnished the liquid nitrogen helium and RP-1 fuel, filters, hoses and the trailers necessary to transport propellants to the complexes.

Primary source for liquid nitrogen is the Base LOX Plant. However, due to unscheduled base plant shutdown and MacDonald-Scott peak requirements, approximately half of the liquid nitrogen was purchased from commercial vendors. Orders on vendors were delivered within 24 hours from Portland, Oregon, via tractor-trailer, and from five to eight days via rail tank cars from Pittsburg, California. Helium (gaseous) was obtained through its only source, the U. S. Bureau of Mines in Texas, with delivery time from 10 to 14 days in Government-owned rail tube cars. RP-1 fuel from Seattle, Washington, was delivered on base via rail tank cars in three to five days.

Unique planning between SATAF and Corps vested local control of Air Force furnished liquids, gases and equipment and Corps' owned equipment under one person, thus eliminating job duplication between agencies, while improving programming efficiency relative to equipment utilization, propellants, and communications with higher headquarters. This planning contributed to lack of any delays caused by propellant shortages and equipment mismanagement.

Trailer equipment units received from upstream bases were in fairly good shape, but new tube bank trailers, both Air Force and Corps contracts, required extensive recleaning. Fortunately, delivery lead time was adequate so that MacDonald-Scott was not delayed.

Quality Control was maintained by continuous inspection of the operation, maintenance and utilization of equipment, surveillance of laboratory sampling and procedures and analysis of contractor manpower.

Summary:

Larson Area was fortunate in being one of the later TITAN I areas and in having the benefit of learning from mistakes made at other bases since the appropriate corrective action for each anticipated problem was forwarded to the area from CEBMCO. Therefore, many pitfalls were avoided. It may be said with pride that many inspectors and technicians who have worked at projects at the Lowry, Ellsworth, Beale and Mt. Home areas, found the quality of construction in the PLS and the conduct and quality of testing at Larson to be the highest they have seen in any of the TITAN I areas.

11. MECHANICAL EQUIPMENT

General:

The mechanical system consisted of a substantial amount of piping, tanks, and duct work, connecting the equipment together so that they would-function as designed. The systems incorporated in the complex were:

a. Supply and Distribution System.

  (1) Low pressure steam and condensate return.

  (2) Treated water (filming amine and softened water).

  (3) Cooling tower water supply and return.

  (4) Chilled water supply and return.

  (5) Hot water supply and return.

  (6) Ethylene glycol supply and return.

  (7) Diesel fuel supply and return.

  (8) Diesel lube oil supply and return.

  (9) Engine jacket water supply and return.

  (10) Diesel exhaust.

b. Water Supply, Storage and Distribution Systems (Domestic and Fire Water).

c. Sewers; Sanitary, Gravity and Sewage Treatment Facilities.

d. General Plumbing.

e. Ventilating System.

f. Air-Conditioning System.

g. Fuel Oil Storage and Underground Piping.

h. Compressed Air Systems (Plant, Utility, Diesel Starting, Filtered and Instrument Air).

i. Blast Closure System.

j. The controls for all of the systems.

All the piping for the above systems, instrument air excepted, was prefabricated and then shipped to each site. Shipping of this material to the right site at the proper time, was one of the contractor's major problems. He handled it well and the installation proceeded fairly smoothly, except for problems as noted below.

Problem Areas:

A supply contract for standardized equipment was awarded to the Nordberg Co., for four 1250 KVA diesel generators for the powerhouse at each complex (a total of 12 generators). The original contract drawings were based on use of Worthington generators. Because of differences in the equipment utilized and that upon which the design was based, the Contractor was required to make major changes in the piping and equipment layout in the powerhouse. This redesign required expenditure of many manhours by Corps of Engineers personnel in checking the revised layout. The use of standardized equipment in many structures adversely affected the contractor's schedule since he did not have effective control over shop drawing submittals by firms he did not select.

The biggest problem encountered in the installation of the piping was the late submittal of piping and pipe support drawings by the contractor. This resulted in his being forced to install piping and supports concurrently with Corps of Engineer review in order to stay on schedule. In most instances, the layout drawings were incorrect and required resubmittals. Thus, when approved shop drawings were finally received in the field, the piping and support were usually already installed and had to be reworked to meet contract requirements. In those instances where piping was workable, but not in accord with approved shop drawings or contract drawings, it was usually accepted without alteration in order not to introduce additional delays that might jeopardize turn-over dates.

Another problem was the sketchiness of the contract drawings and the many unenforceable statements in the contract specifications. For instance, the Equipment Terminal drawings showed a large quantity of flexible hoses in the piping to allow for a shock condition. The wording and pictures on the drawings were such as to lead to the conclusion that all piping must be supported entirely from the various levels. In the case of some of the piping, particularly waste and vent piping, it was finally determined that piping must be supported from the structure shell if hoses were to be located as shown and still operate as intended.

These same drawings specified the location of certain key pipe supports and stated that intermediate supports would be furnished as per specifications. The specifications gave a maximum support spacing only, not taking into consideration the configuration of piping. They also stated that the contractor was responsible for the proper and permanent location of supports. Thus, the contractor was given inadequate criteria and made responsible for a portion of the design by being given full authority to support certain piping where he chose. He could not be made to change an incorrect support or improperly located support, or made to add required support if he met specified spacing, if he resisted such change, without a modification to the contract.

The contractor, according to the specifications, had the option of pneumatic automatic or electronic automatic controls for the ventilating and air conditioning system. He chose pneumatic automatic controls which were installed by the Johnson Service Company.

The contractor was required by the contract drawings to furnish all hot water and hot water return piping in tunnels with Victaulic couplings at 10 feet on centers. By the same drawings, he was required to furnish pipe supports at 14 feet maximum centers for pipe 3" and larger, unless otherwise shown. When the piping was installed, it was discovered that the piping could not be prevented from humping and sagging due to the flexibility of the joints and lack of support at every section of pipe. A modification was issued to install an additional support between existing supports, thereby giving support at approximately 7' intervals. The additional support straightened the piping out considerably, but still did not make a truly desirable installation.

The contractor was required to furnish and install blast valves in accordance with contract design. After the valves were installed and a pre-check for operation was made, it was found that the valves would not latch. A modification was issued to install a redesigned latching dog and heavier springs. It was also found that blast valves in the Powerhouse air exhaust structure corroded rapidly from the diesel exhaust fumes and they soon became entirely inoperative. A protective cover and boot were designed and a modification was issued to correct this deficiency.

Validation:

After completing the installation of a system at each site, the contractor ran an operating test on the equipment or system if required by the specifications, in accordance with a procedure set up by the Corps of Engineers and Air Force. These procedures were revised several times before both parties were generally satisfied with them. As each system was demonstrated, representatives of the Corps of Engineers, the Air Force, and The Martin Company were required to witness the operation and sign that the system satisfactorily passed the procedure. A total of 191 acceptance tests were conducted for the squadron.

During the acceptance procedures, some systems were found to be deficient in one respect or another. Many of the deficiencies were in design and fewer were in construction or operation. In the instance of all submersible pumps and the sewage pumps, it was discovered that the equipment specified did not fit the actual and computed head conditions, and therefore, the motors operated in an overloaded condition.

Most of the systems required some adjustment before they functioned properly.

12. ELECTRICAL FACILITIES

Primary Power

Electrical power at each complex is supplied by four Nordberg diesel generators, net output rating continuous--1000 KW, P.F. 0.80, 60 cycles voltage, 1380/2400 Y, 3 phase, 4 wire. The diesels can be in operation singly or in any combination of 2, 3, or 4 at a time. They are interconnected in a F.P.E. main, 2.4 KW switchboard containing complete AC and DC controls for each unit, plus direct power to the intake fan, 2 fire water pumps, and 2 centravacs water chillers.

The diesel generators and some electrical panels were purchased as standardized equipment by the Omaha District. Supply contracts were assigned to the prime construction contractor for administration.

Five 2.4 KW cables leave the main panel for primary distribution. One goes to a 1000 KVA transformer (2400 to 480 volts) in the Powerhouse. One goes to each Equipment Terminal, terminating in a 1000 KVA transformer. These 2.4 KW cables are 250 MCM in size, 3 conductor, enclosed in flexible metallic conduit with an outer sheath of neoprene. These are routed in a single tray to their destination and are marked and identified every 20 feet as being 2400 volts.

Prime power for the Control Center is also 2400 volts terminating in a 250 KVA transformer producing 480 volt secondary.

Prime power for the Antenna Silos is 480 volts originating at the powerhours main distribution panel and terminating in a motor control center in the antenna terminal.

Secondary Power

Secondary power throughout the complex originates from thirteen motor control centers. There are four in the Powerhouse (MCC-5, 6, 7 & 8) MCC-10 in the Control Center, MCC-11 in the Antenna Terminal, MCC-1, 2 and 3 in the Propellant Terminals, and one in each Equipment Terminal. MCC-9 is located in Tunnel Junction #12 and serves the RP-1 transfer system and components consisting of the air conditioning units, exhaust fan, lighting and sump pumps located in RP-1 storage and Tunnel Junction #12.

These MCC's are a self-contained unit and have a breaker and magnetic starter complete with overload protection going to a disconnect serving each motor. Many also contain H.A.O. switches and relays for control of motors. Listed below is a brief rundown of each MCC and its services:

MCC-9 has already been described above. Its biggest load being the fuel transfer pump P-110 which is 25 HP at 480 volts.

MCC-8 in the Powerhouse feeds the following pumps: P-10, P-15, P-17, P-18, P-19, P-801 and P-801A and also fuel oil centrifuge CE-2, 2 floating valve seal motors and one spare 15 amp. breaker with 2 spare spaces.

MCC-5 in the Powerhouse feeds the following: Ice bank pump P-6; chilled water pump P-4, P-5; exhaust fans EF-1 and EF-2; clean oil return pump SP-5; dirty lube oil pump P-25; mercury vapor lighting; 60 amp. 3-phase receptacles; ice bank compressor CU-1 and CU-2; lube oil centrifuge CE-1; deep well pump SP-4; cooling tower #1 fans CT-1A and CT-1B; cooling tower pump P-1; sump pump SP-923; ethylene glycol circulating pump P-7; diesel engines #3 and 4 jacket water pumps; 1, 70 amp spare and 1 spare space.

MCC-6 in the Powerhouse feeds the following: Jockey pump P-23; raw water pump P-35; sump pump SP-924; 60 amp. 3-phase receptacles; portal power pack, portal sump pump SP-925; portal elevator; lighting panel P/A, chlorinator control; water system controls; feed to MCC-9; utility air compressor C-4, starting air compressor C-3, and 2 spare spaces.

MCC-7 in the Powerhouse feeds the following: Condensate pumps CP-1, CP-2 and CP-3; hot water system pumps P-8 and P-9, diesel engines #1 and 2 jacket water pumps; sewage ejectors #1 and 2; deep well pump SP-3; 60 amp. 3-phase receptacles; cooling tower #2 fans CT-2A and CT-2B; cooling tower pumps P-2 and P-3 (standby) and 4 spare spaces.

MCC-10 in Control Center feeds the following: 2 lighting panels; pantry power panel; radiation and wind detectors; 3 MG sets NIC; air compressor CC-1; exhaust fans EF-1 and EF-3; 2 sewage ejectors; sewage shredded; AC units #1, 2 and 3: and supply fan SF-1.

MCC-11 in the Antenna Terminal feeds the following: Pumps P-1, P-2, P-3 and P-4; AC Units #1, 2 and 3; instrument air compressor, sump pumps SP-945, SP-946 and SP-947; east and west silo elevators; power packs #1 and 2; 2, 60 amp. 3-phase receptacles; lighting panels; sewage plant motors and 1, 30 amp. spare.

MCC-1 in the Propellant Terminals feeds the following: LOX vacuum pumps P-701, P-702 and P-703; sump pumps; air circulating fan EF-2, LOX blower P-303, LOX air conditioning; lighting panel; 60 amp. 3-phase receptacles and 4, 15 amp. spare spaces.

MCC-2 in the Equipment Terminals feeds the following: Two 25 HP missile silo sump pumps; fuel unloading pump P-111; fuel line drain pump P-112; LOX unloading pump P-201; exhaust fan MS-EF-1; 1.6KW air dryer; 30 HP air compressor; Level I AC units #1 and 2; air compressor CC-1; Level I power receptacle; 60 amp. 3-phase; exhaust fan EF-1; Level 2 AC unit #3; elevator 100 amp. switch; Level 3 AC unit #5; Level 4 AC unit #6; 3 KW transformer; chilled water booster pump, P-5; hot water booster pump P-6 and 3 spare spaces.

Alarm Systems:

The following is a rundown on the alarm systems on the complex:

a. Fire detection system actuated by increase of temperature up to 140°F.

b. Gaseous oxygen detectors actuated by barometric pressure change of 0.5 inches HG and oxygen content of atmosphere.

c. Fuel vapor detectors actuated by fuel gas concentration of from 0.1 to 0.9 per cent by volume.

d. Anemometer indicating from 0 to 100 mph. wind velocity.

e. Explosion detectors.

f. Radiation detectors inside facility are actuated when radiation level reaches the level of 0.15 roentgens per hour. Four radiation sensors at instrument mount may be selected and read on C.C. alarm panel. Range 0-5K/RH.

g. Liquid oxygen spillage detectors actuated by low temperature.

h. Blast detectors actuated through sensing heads furnished by the Government.

These alarm systems have local visual and audible alarms, and also register in the Control Center alarm panel.

Included in the alarm systems is a position indicator of all blast doors and blast valves.

Emergency Lighting

Emergency DC lighting is installed throughout the entire complex. The Powerhouse, Control Center, and Equipment Terminals have a 120 volt bank of batteries complete with charger to serve them.

The DC system in the Powerhouse serves as emergency lighting and also controls for diesels and alarm systems.

The DC system in the Control Center serves as emergency lighting and also operates the controls for the alarm system in the Control Center, Entry Portal and Instrument Mount.

The DC systems in the Equipment Terminals provide power for the Equipment Terminals, Propellant Terminals, Missile Silo emergency lighting and controls for all alarm systems.

All tunnels, junctions, blast locks, antenna silos and antenna terminal are served by individual battery operated lights. These consist of a 6-volt battery operated one or two 25 watt lamps which automatically come on when prime power fails. The batteries are kept charged by a trickle charger with high and low ranges.

All battery bank panels are provided with a ground indicator light on both positive and negative sides to warn against possible drain of batteries due to a short or ground in the emergency DC systems.

Grounding and bonding was a major electrical item. Ground mats were installed under each structure and bonded to reinforcing steel by an exothermic method. Reinforcing steel was bonded by welding. Grounding plates and conductors were also installed. Structural steel was bonded by grounding conductors and lugs. All structures were bonded together by a parallel grounding network. Motors, motor control centers, substations, generators, etc. were also grounded.

Problems Encountered

a. A major problem was adapting the standardized equipment to the contract layout. In the case of the Powerhouse, the contractor was obligated to do some redesign and make many modifications to correlate items.

b. Considerable difficulty was experienced in obtaining shop drawings from various manufacturers--particularly the Westinghouse Company, who furnished the switchgear. Shock test data was also slow. Record keeping and expediting of these items was a considerable task.

c. Lack of correlation of various trades on design drawings caused some conflicts and discrepancies during construction. A few of these were conflict of tunnel lights with RP-1 piping, and conflict of lighting fixtures with mechanical items in the antenna silos and junctions.

d. Grounding became quite a problem, because of a difference of opinion on exactly what had to be grounded. All the ring beams and re-steel were grounded by 4/0 copper wire to copper rods which were driven into the earth at several different elevations. Grounding plates were imbedded in the concrete silo walls and were also connected to the 4/0 copper wire. Every piece of equipment was grounded to the crib steel and in turn the crib was ground to the aforementioned grounding plates in the concrete wall. Bonding straps were placed across flanges and valves throughout the silo and remainder of propellant loading system. All flexible joints on ducts and cable trays were also bonded.

e. Contract drawings and specifications were ambiguous in many details, such as requirement for penetrating concrete fire walls, locations of explosion-proof installations, etc. Some of these items were clarified by change order and some by letter, depending on the circumstances. A total of 39 change orders were issued for electrical work. They are listed below:

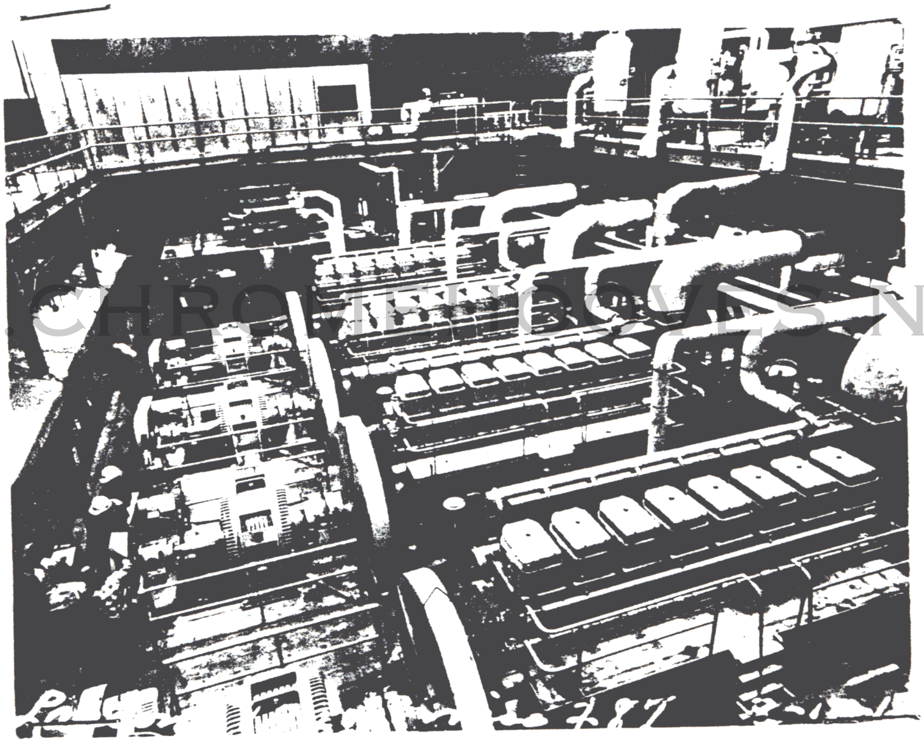
C.O. No.	Description
10	Bonding Propellant Terminal Reinforcing Bars
14	Grounding Mat Resistance
23	Grounding and Bonding in LO_2 Bays
34	Telephone Terminal Cabinets
37	Additional Grounding Plates in Powerhouse
38	Wire Limit Switches for Valves CV-160, CV-161
41	Cable Trays, Level III and IV - Equipment Terminal
42	Flexible Conduits to TTC-5, Equipment Terminal
55	Additional Conduit from Junction Box Beneath Level I - Equipment Terminal

C.O. No.	Description
57	Relocate 4-inch Conduits in Control Center Roof
60	Revise Equipment Terminal Cable Trays to Clear Spring Beams
61	Stranded Wire for Instrument Wiring in PLS System
63	Relocate Fluorescent Light Fixtures in Antenna Silos
80	Modify Cable Tray Supports in Utility Tunnel
84	Deletion of Three 2-inch Conduits in Control Center
87	Revise Cable Tray on Level IV Equipment Terminal
95	Transformer Support - Level IV Equipment Terminal
96	Modify Junction Boxes in Missile Silo
117	Circuit for Test Control Station
121	Grounding LOX Tank Supports
125	Revision of 12-inch Cable Tray in Antenna Terminal
135	Modify Indicator Lights for Fuel Transfer Panel
136	Modification of Controls and Addition of Alternators for Contaminated Waste Pumps - Sched. J
144	Modify Cable Trays under Raised Floor - C.C. Operations Room
145	Re-route Cable Trays in E.T.
146	Pushbutton Requirement Change - Propellant Terminal
147	Micro-Switch Designation - E.P.
152	Additional Panel Changes Schedule A
153	Misc. Changes - Liquid Sensors, Transfer Panels - Sched. A
189	Revised Conduit Layout - A.S.
194	Relocate Lighting Panel CCB
196	Relocate Alarm Panel, Terminal Board and T.V. Monitor
215	Firewater Pump Control Relays
224	Cable Trays, Penetrations and Conduit Elevations - E.T.
226	Modify Power Panels P-E1 and P-E2 - P.H.
243	Modify West Light in Communications Cable Vault
271	Modify Lighting Fixtures in Control Center
276	Powerhouse Annunciator Panel - Schedule I
353	Modify Pressure Selector Relay on Air Conditioning

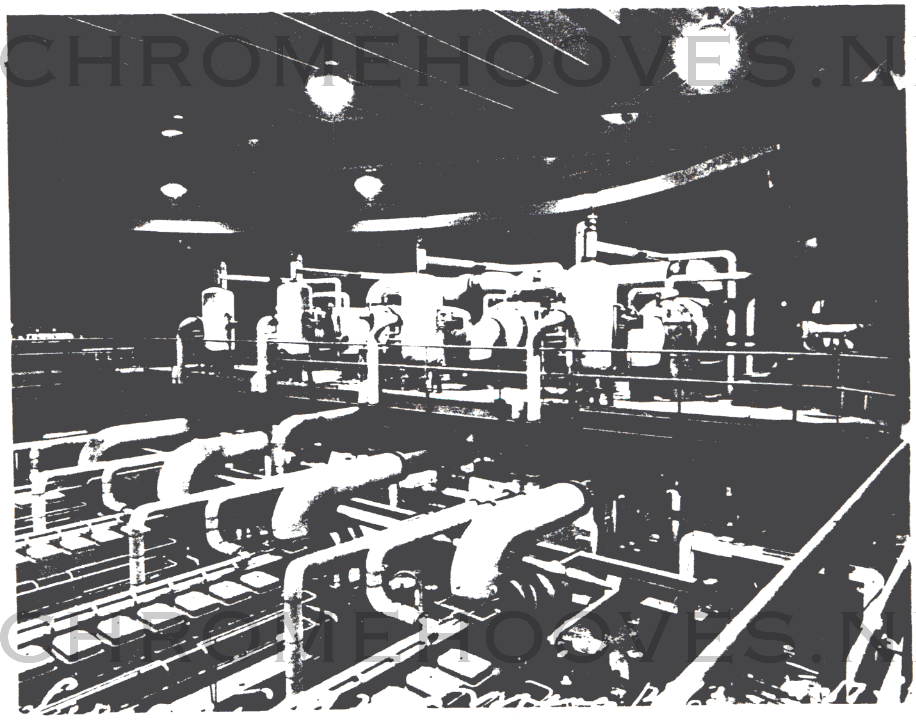
f. Concurrent construction and associate contractor design and installation created several problems, particularly in the Antenna Silos. This made it necessary to modify work which had already been completed.

Validation

Validation of electrical equipment was accomplished in accordance with the specifications. It was done in conjunction with the mechanical items as a normal practice. All tests were coordinated with Air Force and Martin Company representatives.



COMPLEX 1-A - POWERHOUSE (Figure 20)
Four, 1000 KW, 60 cycle, 1380/2400 Y, 3-phase, 4-wire, Diesel Generators



COMPLEX 1-A - POWERHOUSE (Figure 21)
Vapor phase Separator on mezzanine. Note overhead 10-Ton capacity Polar Crane