** Pages Missing **

There are four pages (21 through 24) missing from this document:

Page 21-23: "Mechanical Subsystems"

Page 24: IV-B-4-1, "Propellant Transfer System" (fold-out diagram)

b. Water

Present Titan I water systems will remain unchanged except for the systems within the missile silo. Wherever possible existing valves, controls, etc. now in the silo will be salvaged during the tear out operation and reused.

The Titan IIA Design requires a spray ring for the delivery of a large flow of water to the silo booster engine area for sound suppression during the launch sequence. This water will be delivered to the silo through the present water distribution system. Installation for the silo will be made. The operation of the system will be interlocked to the launch sequence.

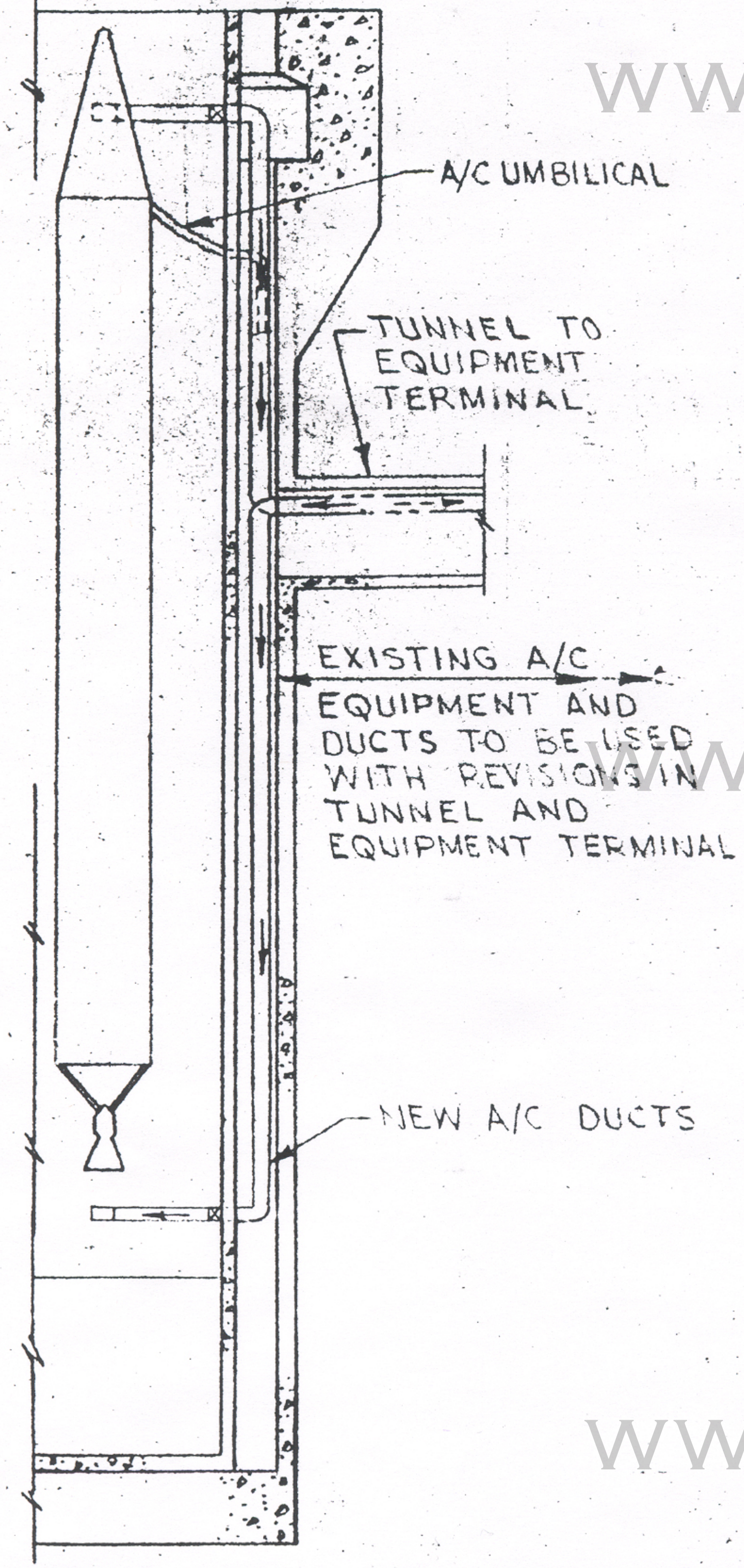
The other major water requirement for the Titan IIA consists of a water deluge system to wash down the missile and silo walls in the event of a propellant catastrophe. In such an event the quantity of water required would be too large to be drawn from existing storage facilities. The added storage capacity for this system will be provided by converting the existing fuel tanks. Distribution to the silo will be made through the existing fuel lines.

c. Air Conditioning

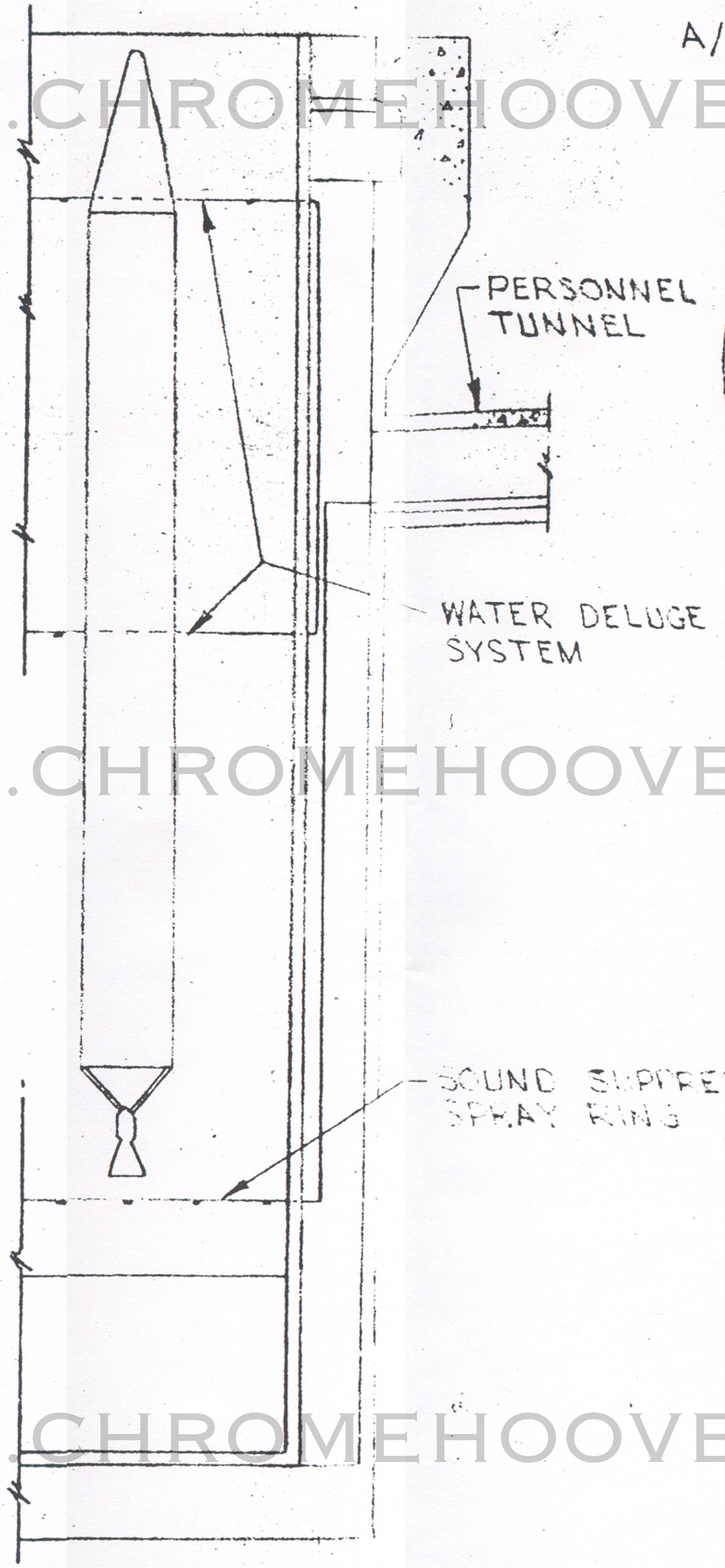
The present air conditioning units in the equipment terminal will be retained for Titan IIA use with minor revisions. New ducts will be designed and built to service the new silo configuration. The new duct work will be connected to the present exhaust ductwork that vents to atmosphere sensors to detect toxic fumes will be required to change the air conditioning system from normal recycle condition to purge condition.

d. Hydraulics

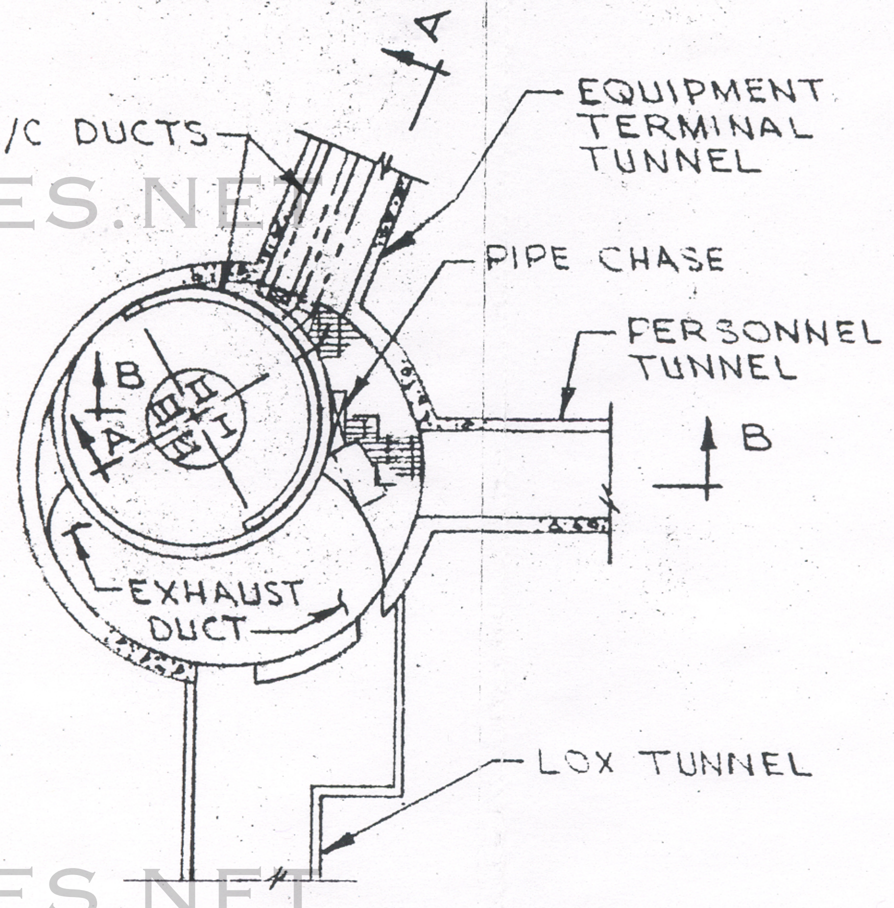
Equipment terminal hydraulic pumps will be retained and used to supply power to operate the work platforms and the silo door. Present Titan I hydraulic units will be adapted for reuse with Titan IIA wherever possible. One example of probable adaptability would be work platform jacks.



SECTION A-A



SECTION B-B



SILO PLAN
ACCESS TUNNEL LEVEL

MISSILE SILO AIR CONDITIONING AND WATER SYSTEMS

SCALE 1" = 20'
27 SEPT. 63
A.K.P.L.

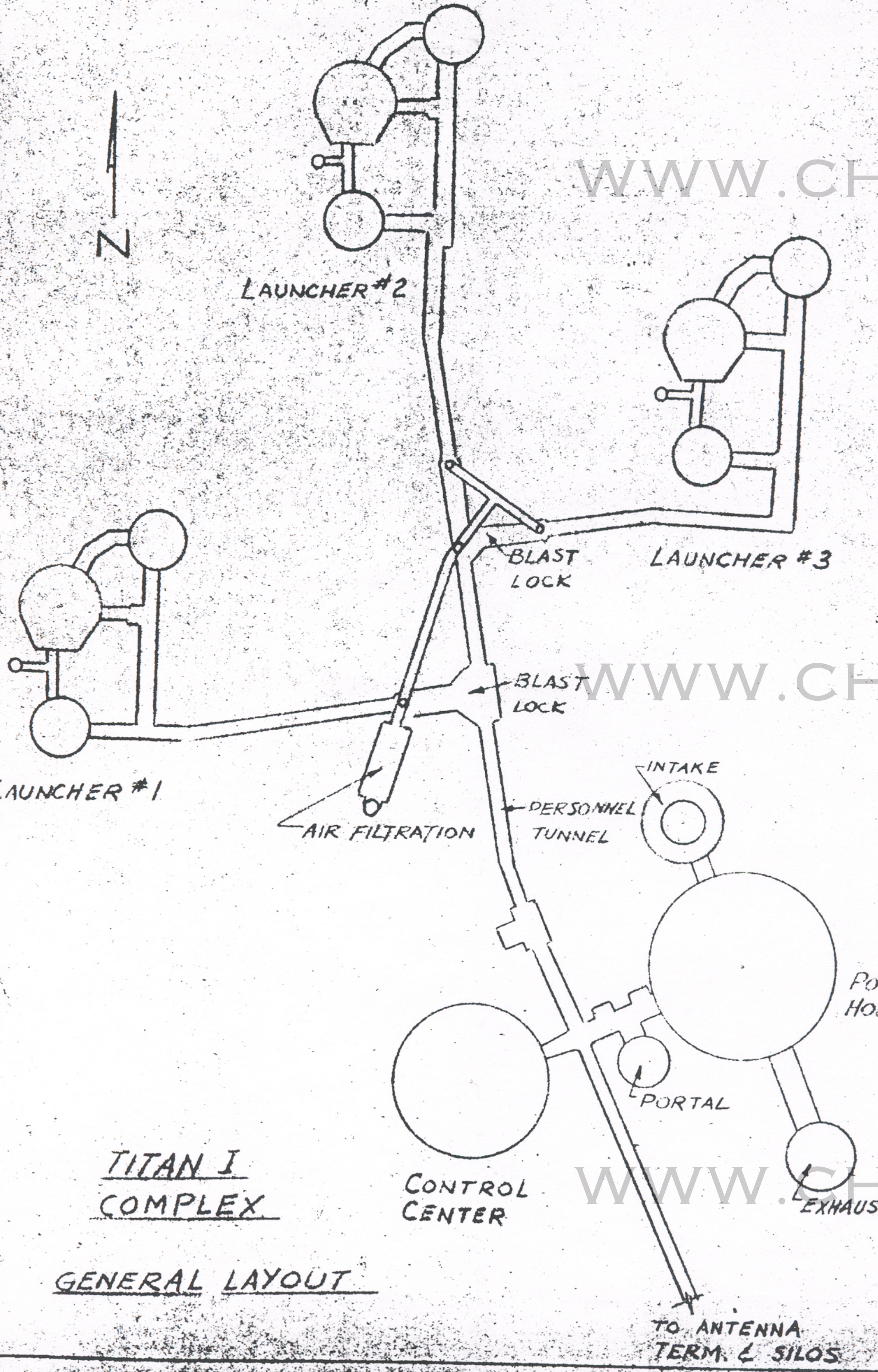
FIGURE IV-B-4-2

5. Structural Subsystems

a. Titan I Complex General Layout (Reference Fig. 5-1) - Each complex consists of 3 launchers supported by one control center, one power house and two antenna silos. Each launcher is isolated from the control center-powerhouse-area and each other by a blast lock which provides personnel protection in event of a launcher area mishap. Required major structural modification is limited to the missile silo structure. These modifications are defined on figures 5-2 and 5-3.

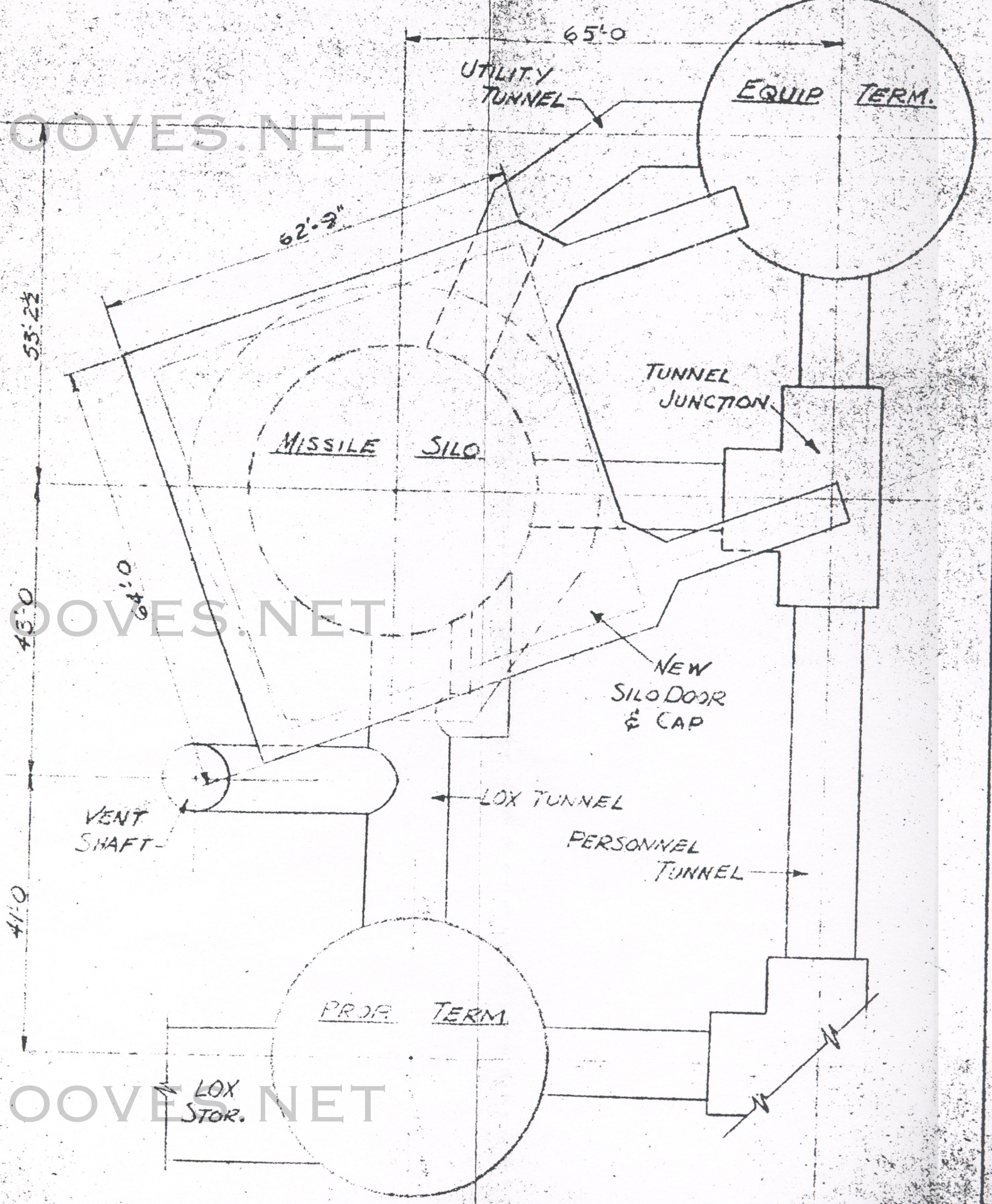
b. Silo Size Criteria - From a gas dynamics standpoint, satisfactory silo operation can be obtained for the Titan IIA vehicle in the Titan I silo by using a "U-tube" arrangement. Launch duct and exhaust duct areas of 472 ft^2 and 360^2 ft^2 respectively will provide a secondary air flow sufficient for an entrainment ratio of approximately 1.4 (Ref. 1). This value was obtained by assuming the engine exhaust was 56% gaseous and computing the entrainment ratio considering only the gaseous exhaust as affecting the secondary air flow. Afterburning was considered but heat transfer to the wall was neglected. Calculations were made assuming a loss coefficient of 2.0.

Transient overpressure due to engine ignition will range from 6.0 to 9.5 psig. These overpressures were calculated using a step-funtion input with engine mass-flow rate stepping from zero to steady-state condition (Ref.2). Gas temperature in the lower portion of the silo during engine ignition will be between engine exit static temperature and engine chamber temperature. Therefore, these temperatures represent the limiting cases and account for the range indicated for the transient overpressure. Transient overpressures were computed considering only the gaseous portion of the exhaust with an afterburning coefficient of 1.2. The afterburning coefficient gives a conservative result since only limited afterburning can occur prior to the establishment of secondary air flow water injection was not considered.



TITAN I COMPLEX

GENERAL LAYOUT



TYPICAL LAUNCHER

PLAN

FIG. IX-B-5-1

Primary areas requiring further study are:

1) Refinement of transient overpressure calculations when data on engine thrust build-up becomes available.

2) Evaluation of the radiant-heat problem in the missile base due to aluminum oxide particles in the exhaust.

It is felt that study item 1) will result in significant reduction in the indicated transient overpressure due to rarefaction waves reflecting from the silo opening interacting with compression waves emanating from the engine. Test data from the Titan IIA program will be available to aid study item 2 within the next 6 months.

The modified silo provides (Reference Fig. 5-2):

- In-silo fly-out launch
- Launch duct area of 472 sq. ft. (identical to Titan II)
- Exhaust duct area of 360 sq. ft. in an efficient "U" configuration.
- Adequate access and fixed platform area.
- Optimum relationship between launch duct and existing utility tunnel to minimize piping, ducting and cabling runs.
- Good access routes for personnel ~~vice~~ via existing personnel tunnel and reused personnel elevator.
- No impairment of the structural integrity of the existing missile silo.
- Location of azimuth alignment set within the silo walls to minimize costs.

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1. C. N. Tsu "A One-Dimensional Analysis of Ducted Silos and a Method of Scaling Model Test Data of Air Entrainment to Full-Scale." Space Technology Laboratories, Inc. TR-59-0000-00759.

2. P. R. Ilgen & R. J. Heyman, "Cold Flow Studies of the Aerodynamic Performance of a Concentric Silo Launcher for Titan-Amendment 1." The Martin Company SR-60-34-Vol. II.

- Readily adaptable launch duct by use of composite construction (steel plate and concrete) allowing easy attachment of acoustic liner and brackets.
- Minimal construction time through prefabrication of steel plates for both launch and exhaust ducts.
- Use of shock isolation system and thrust mount proposed by Titan IIA Study Program.

The existing silo requires removal of:

- Silo doors and the silo cap to 12' below grade.
- All items within the confines of the silo.

c. Blast Hazard Criteria - When a Titan IIA missile is placed in a Titan I silo, the resulting blast hazard to personnel and facility components is not considered critical from the structures standpoint. An evaluation of the TNT equivalent of the propellants of each missile produced the following results:

The Titan I propellants have a TNT equivalent weight of approximately 84,000 lbs., based upon a TNT equivalent of 40%. Results of a Martin Company test program to determine the TNT equivalent of the Titan IIA propellants are not yet available. However, preliminary evaluation of test data indicates a 5 to 10% TNT equivalent. Based upon a 10% TNT equivalent, the Titan IIA propellants have a TNT equivalent weight of approximately 44,000 lbs. This is approximately 52% of the Titan I TNT equivalent.

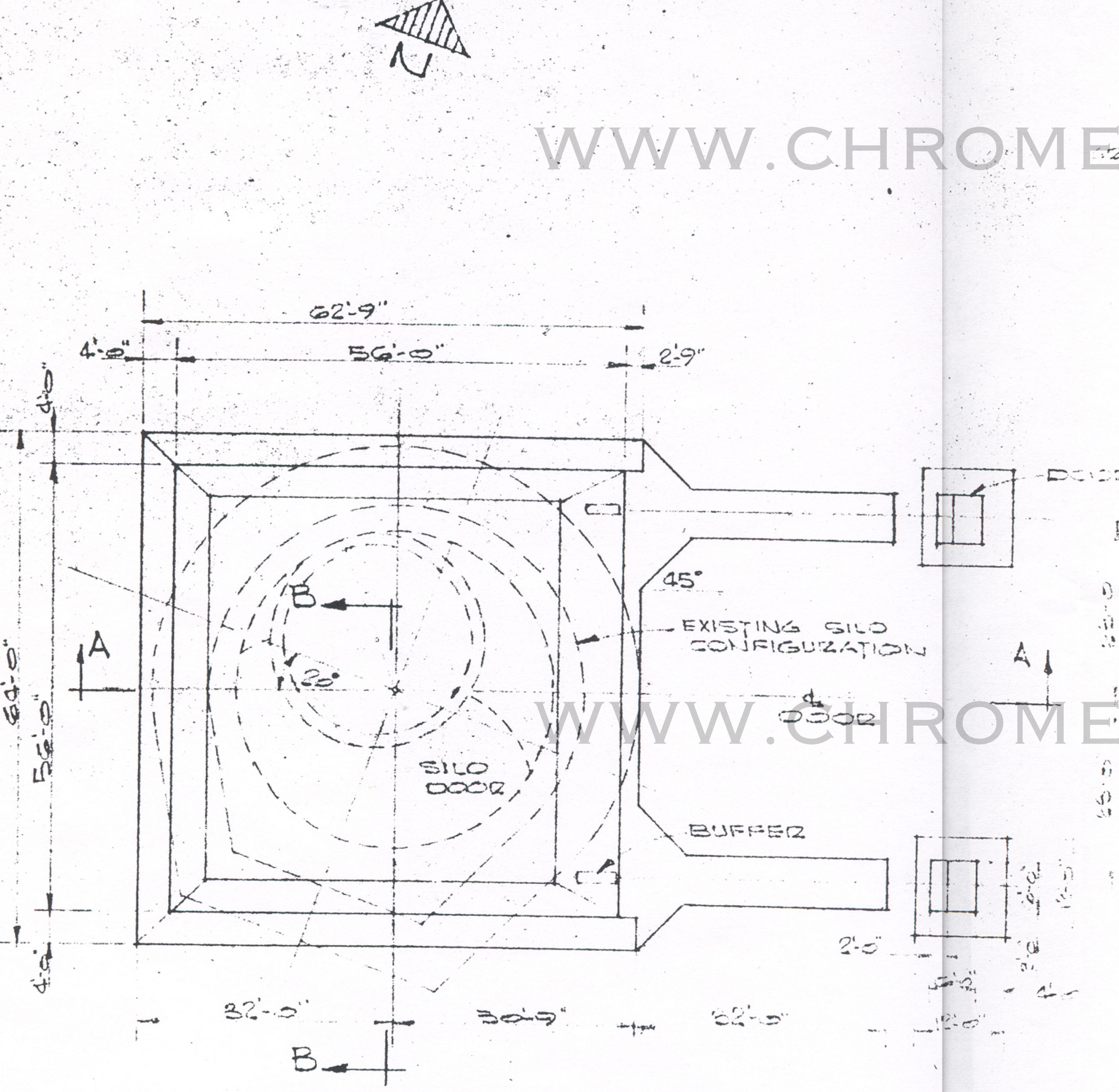
The existing blast protection system through the blast doors and blast locks is more than adequate to protect the launch complex from the blast hazard of in-silo missile explosion.

d. Launch Silo Door (Reference Fig. 5-3) - The silo door will consist of two steel plates, 3 inches in thickness and separated by steel webs. The door will be 56 ft. square, 4 ft. deep, and span a circular opening of approximately 45 ft. diameter. When in place, the door will be lowered on bearing plates to resist the blast loads. These plates will be placed around the periphery of the circular opening and embedded in the reinforced concrete silo cap. Tie-downs will be provided to prevent vertical movement of the door during blast and shock loadings.

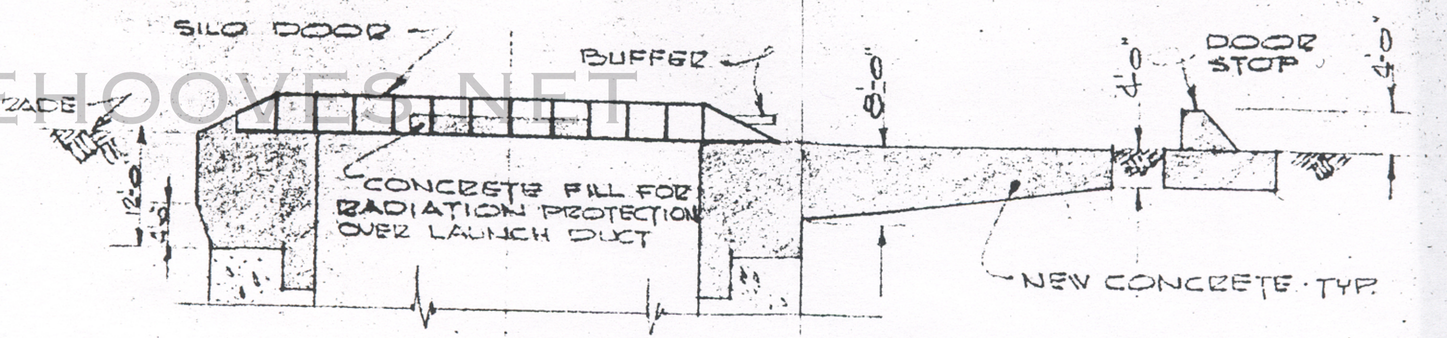
The door is designed for dynamic blast loads, a peak overpressure of 100 psi, and ground shock loads. In addition to these loads, the door i carries all static loads.

Continuous sealing of the door, around the outer edge, will be provided to completely isolate the missile from the weather, blast pressure, and nuclear fall-out. In addition to the steel in the silo door, non-reinforced concrete will be placed over the launch duct area for nuclear radiation protection. This concrete can be placed in the void between the steel plates in the silo door.

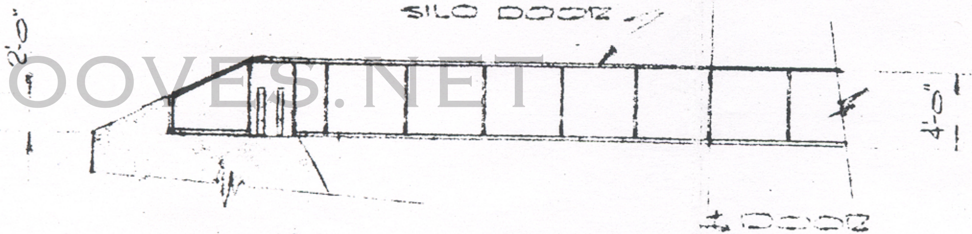
The door will be mounted on four sets of wheel trucks placed on heat treated crane rails for mobility. The door is lowered by means of hydraulic jacks placed under a section of the rails. When the door is in place and sealed the blast loads will be transmitted to the bearing plates only. The front edge of the silo door will be equipped with a plow-edge for removal of the debris on the truck rails andthe area in front of the door. The drive mechanism for opening and closing the silo door will consist of a wire cable system and hydraulic motors somewhat similar to that of the Titan II Launch Silo door system. Buffers at the ends of the cantilevered rails and on the back edge of the door jam will help cushion the door when opening and closing. These buffers are also similar to those used on the Titan II complex.



PLAN



SECTION 'A'



SECTION B

LAUNCH SILO DOOR

FIG. IV-B-5-2

The door design is based on structural grade steel for the plates and webs in the door, 3,750 psi concrete for bearing, and static analysis with the use of a dynamic load factor. The door is considered as a flat circular plate simply supported on the outer edge. The webs provide lateral stability and carry the shear in the door. The cantilevered rails are an integral part of the concrete silo cap to insure against differential displacements of the silo and rails due to the blast loadings.

The silo door (Reference Fig. 5-3) provides:

- Use of proven construction and operation methods.
- Reaction time equal to that of Titan II.
- Use of existing hydraulic power source.
- Maintenance of facility hardness.

e. Silo Structural Modifications (Reference Fig. 5-2)

1. Tearout - In order to accommodate a Titan IIA missile in a Titan I silo, it will be necessary to completely remove all of the structures and equipment contained inside the silo. The present silo doors must also be removed in order to accommodate the in-silo launch concept. A new door configuration will require the removal of the top 12' - 0" of the existing silo structure.
2. New Construction - Major items to be constructed and/or installed in the Titan I silo include the following:
    (a) The silo cap - will be a reinforced concrete structure attached to the existing silo walls. It is 40' I.D. with walls approximately 7' - 6" thick at the intersection with the existing silo. It

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References:

"Ultimate Strength Design of Reinforced Concrete", No. 53-25, Whitney & Cohen

"Advanced Strength of Materials," Don Hartog, McGraw-Hill Book Co.

Technical Documentary Report No. AFSWC-TDR-62-138.

extends 12'-0" upward to form the new door. At the top, the cap is 64'-0" x 62' - 9" with 32' - 0" long cantilever beams to support the door in the open position.

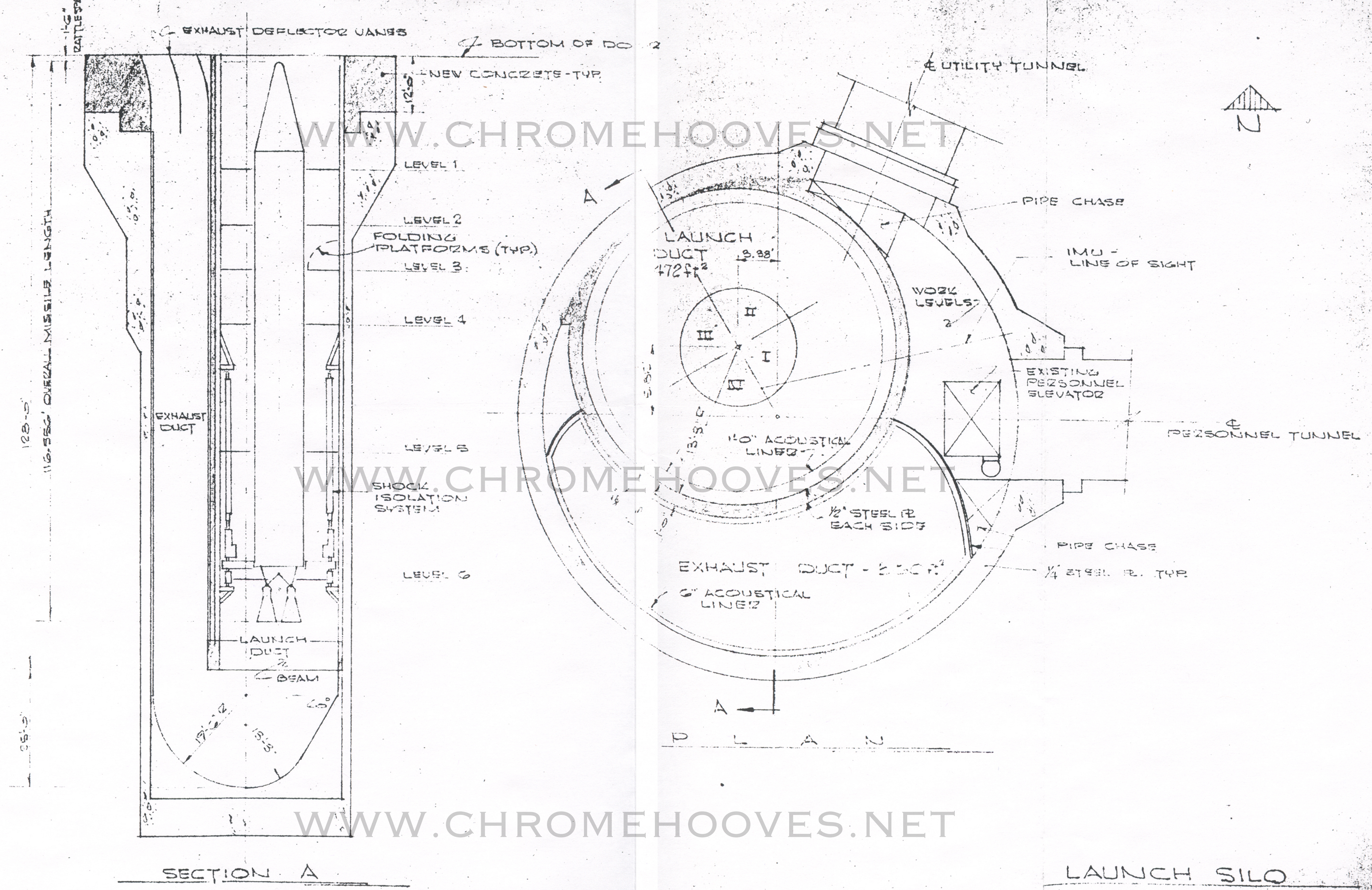
(3) The Launch Duct - will be a composite steel-concrete structure. It is 26' - 6" I.D. with 1'-0" walls and is 128'-0" long. The walls are faced with ½" steel plates on either side. The steel plates eliminate the need for concrete forms, allow easy application of required anchors, and can be prefabricated to minimize installation time. The launch duct is located "off-center" in the existing silo and is anchored to the walls on one side. In addition a reinforced concrete beam is provided for support at the base.

Steel folding platforms are located on the inner wall at each of the six work levels. Access doors are provided to permit passage through the launch duct at each work level. Steel brackets are located on the inner wall to provide attachment points for the missile shock isolation system.

(4) The Exhaust Duct - utilizes most of the remaining space between the exterior of the launch duct and the existing silo. Steel plates are used to complete the exhaust duct envelope. They are designed to contain the exhaust gases and are flexible so as to not restrain the existing silo walk from deflecting when subject to an exterior pressure.

(5) The Flame Deflector - will be a reinforced concrete structure placed in the bottom of the existing silo. It is anchored to the base and walls of the silo and formed to direct the exhaust gases upward into the exhaust duct.

(6) Work Platforms - Steel work platforms will be installed in the area outside the launch and exhaust ducts to provide access to the six work levels.



LAUNCH SILO

FIG. IV-B-5-3

(7) Personnel Elevator - The personnel elevator and associated equipment, removed from the Titan I crib structure, will be installed using new supports anchored to the existing silo walls. The elevator provides access from the personnel tunnel to the six work levels.

(8) Collimator Pedestal - The collimator pedestal will be a reinforced concrete structure anchored to the inside of the existing silo walls. It will provide a vibration free support for the autocollimator.

f. Shock Isolation System (SIS) - The SIS will be identical in concept with the Titan II (AF04(647)-612,746) SIS except that the dampers will not be required. The load carrying capability will have to be increased over that of the Titan II SIS due to the increased missile weight. System parameters were chosen so that the feasibility of the system with respect to stability and loads could be examined.

The resulting system had a longitudinal frequency of 0.88 cps, and pendulum and pitch frequencies of 0.07 and 0.26 cps. The ground shock spectra used were the 100 psi overpressure curves from Ground Shock Criteria for Atlas, Titan, and Minuteman by Dr. B. Sussholz, STL Memorandum GM-60-0000-12196, 8 April 1960 (Secret). The loads were calculated assuming the missile was a rigid body, but this approximation was proven to be valid for the Titan II missile. The loads resulted in a load factor of 1.8 gravities at the tailskirt which is less than the planned design allowable. For an optimum system this load factor could be reduced. For stability it was decided to use vertical springs such that the resulting rotary spring constant was 1.5 times greater than the destabilizing moment. The Titan I SIS presently in the silo will not satisfy the necessary criteria and must be removed for exhaust duct space requirements.

The Titan IIA SIS now being developed under Martin study contract is identical in concept with the Titan II (SM-68B) SIS except that dampers are not required. Thus this SIS does meet the necessary requirements and will be used in the Titan I silo.

g. Acoustic Considerations for Titan IIA in a Titan I Silo - During a silo launch, some portions of the missile may be exposed to acoustic levels that exceed the above ground or flight environments. Two exceptions might be the nose cone and the second stage engine compartment. The increase in the excitation amplitude in these two compartments on Titan IIA, however, should be comparable to the increase in the Titan IIA silo acoustic environments as compared to Titan II. This discussion, therefore, will be concerned with the in-silo environments.

The acoustic power level of the Titan IIA was found to be approximately 204.5 db or 1.5 db higher than would be calculated for Titan II. The acoustic intensity within the Titan IIA silo can also be compared to the Titan II silo by consideration of the cross-sectional areas. The spectr~~ums~~a were found by comparing the Titan IIA and Titan II Strouhal numbers (5.95×10^{-4} to 6.06×10^{-4}). Thus, the in-silo rocket engine noise environment for Titan IIA would be approximately 2.5 db higher than Titan II. The sound pressure level at the top and bottom of the missile can then be determined by scaling Titan II data as shown in the attached figure. The levels, as shown, are the maximum that would be seen at any time during the flight out of the silo. The Titan IIA components can survive these acoustic excitation environments and no testing will be required.

Some effort, however, will be required on the acoustically induced vibration environments. If the Titan IIA vehicle structure is assumed to be similar to the Titan II, the structural transfer function remains relatively constant and the vibration amplitude increases linearily with the sound pressure level (for small amplitude changes). One exception may occur in

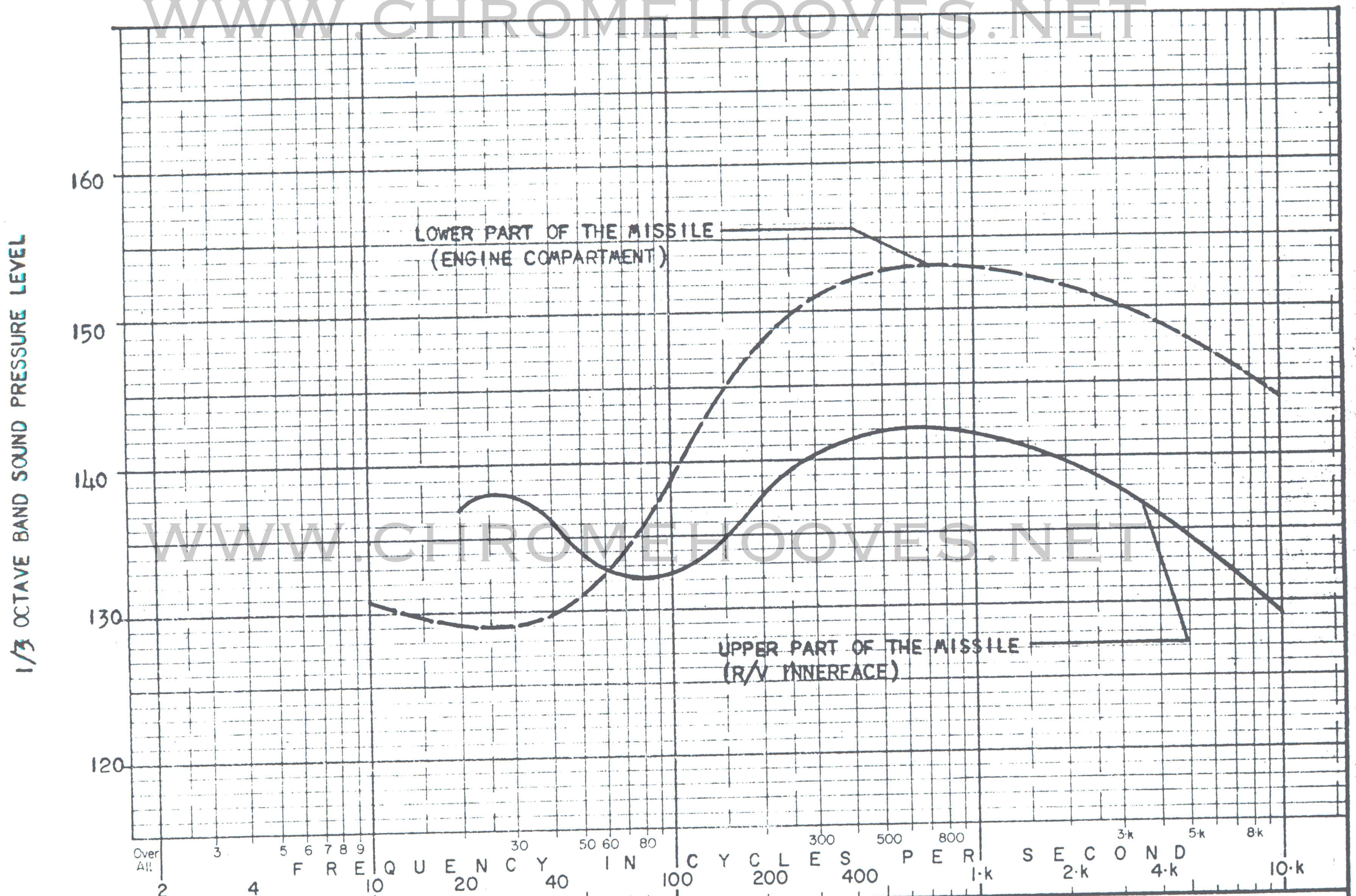


FIG IV-B-5-4

SYMBOL LEGEND

PREDICTED TITAN II-A ACOUSTIC ENVIRONMENTAL LEVELS

FIGURE

the above silo noise field where the spatial distribution of acoustic energy will differ from that of Titan II. This change should be small and may possibly lower the vibration levels on some components. Thus, the vibration amplitudes for Titan IIA should be within 3 db of the Titan II vibration specifications. The results of vibration tests have indicated that these components would survive an environment 3 db higher.

Because of the similarity of components, it is assumed that no significant vibration problems will occur on Titan IIA and that a limited amount of testing will be required. Acoustic liner will be required in both the exhaust duct and launch duct. The specifications will be similar to Titan II except that perforated steel plate will be used as a facing material.

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1) W. Butler: "Acoustic and Vibration Measurements from the SLTF Program" MI-61-47, November 1961. Martin Report-Confidential.

2) R. Loya, et.al., "Scale-Model Test of Silo-Type Ducted Launcher Vol. II. Feasibility and Design Criteria," AFBMD-TR-60-39 (II), April 1960, Conf.

3) "Acoustical Environment Associated with Silo Launch of a Full-Scale Minuteman," Bolt, Beranek and Newman Inc., Rept. No. 716, MI-A-61-1000, November, 1960, Confidential.

4) "Measurements of Acoustical Spectra in the 1/3 Scale Minuteman Silo", Bolt, Beranek and Newman Rept. No. 705, AI 60-13093, 11 May 1960-Conf.

5) F. M. Condos, et.al., Silo Launch Technical Investigations Final Report, Vol. I thru IV, CR-60-22, November 1960.

6) R. Peverley and H. N. McGregor; Above-Silo Acoustic Measurements, VS-1 Captive SLTF. Martin-Denver Internal Report.

6. **Logistics** - The cost of logistic support, maintenance, training, spare parts, technical manuals, tools and test equipment of the Titan IIA will be significantly reduced due to the following design features.

The above design features would indicate a savings in logistic support costs of 25% over Titan I. Large additional savings in logistic costs may be realized through the simplification of the Titan I powerhouse systems via an up-date program proposed in the text.

a. Organization Maintenance of Titan IIA in the Titan I Complex (Reference Fig. 6-1) - Far less maintenance will be required in support of the Titan IIA than is required with the Titan I. This is primarily due to the fact that less AGE is involved in the weapon system. The simplified propellant transfer system and the all inertial guidance system are examples of simplified AGE requirement. Additionally, the RPIE systems are reduced or eliminated. The propellant terminal and antenna silo RPIE are no longer required and large portions of other RPIE will be deactivated and will require no maintenance. The three sets of launch control and monitoring equipment provides for an increased capability to launch in an emergency condition. If malfunctions in one set of launch control and monitoring equipment prevent immediate launch, the equipment may be returned to servicable condition through the borrowing of chassis from the other sets of equipment. This could mean the difference between launching the weapon or not. This, of course, simplifies the emergency maintenance problem to one of malfunction isolation and plug-in replacement.

A new maintenance problem has been discovered and is under continued study. The thixotropic fuel clings to tank and plumbing surfaces in a thin jell film. A search is underway to develop a suitable cutting/cleaning agent for missile tank decontamination. This problem arises only when missiles must be downloaded and the fuel tanks entered by personnel. A solution to this rarely encountered problem is being studied by Martin-Denver in-house funded study.

ORGANIZATIONAL MAINTENANCE OF TITAN IIA IN TITAN I COMPLEX

MAINTENANCE REDUCED DUE TO:

- REDUCTION IN AGE REQUIRED
- DEACTIVATION OF MANY RPIE SYSTEMS
- INCREASED EWO STATUS DUE TO REDUNDANT LAUNCH CONTROL AND MONITORING SYSTEMS

NEW MAINTENANCE PROBLEM -

- FLUSHING/CLEANING FUEL TANKS IN THE DOWNLOADED MISSILE (PROBLEM IS UNDER STUDY NOW)

Figure IV-B-6-1

b. Titan I MAMS Conversion to Maintain the Titan IIA (Reference Fig. 6-2) - The Titan I Missile Assembly and Maintenance Shop (MAMS) requires only minor modification of the building to accommodate all the normal field maintenance functions to be performed on Titan IIA. These modifications are different for each MAMS since the original buildings were different. By functional areas, the Titan I Lox cleaning area will be converted to a part decontamination area and a section of the central bay will be outfitted for missile decontamination. Other facilities to be added are a SCAPE suit repair area and an enclosed missile tank flushing area.

Preliminary estimates indicate that conversion should cost approximately 5% of the original MAMS cost for building and outfitting. This conversion will take approximately two months.

Most of the Titan I MAMS equipment will be applicable to the Titan IIA since it is general purpose equipment. However, some weapon system peculiar equipment will be required for testing and repair. This equipment is essentially the same as is found in the existing Titan II MAMS.

The conversion of the Titan I MAMS to Titan IIA operations is not only feasible, but economical. No loss in need field maintenance capability is foreseen.

c. Spare Parts for Titan IIA (Reference Fig. 6-3) - The Titan IIA program will have a more economical spare parts program than the Titan I primarily because there will be less equipment requiring spares support. The deactivation of large amounts of RPIE has been previously noted. The design of the Titan IIA system requires considerably less AGE than Titan I. The redundant use of three sets of launch control and monitoring equipment means that the need for an immediately available spare is not as great.

TITAN I MAMS CONVERSION TO MAINTAIN TITAN IIA

AREAS DELETED	AREAS ADDED
LOX CLEANING	DECONTAMINATION
	TANK FLUSHING
	SCAPE SUIT REPAIR

CONVERSION COST = ~ 5% OF BLDG. COST

CONVERSION TIME = ~ 2 MONTHS

LOSS OF FIELD MAINTENANCE CAPABILITY IN THE CONVERTED MAMS = NONE

Figure II-B-4.2

SPARE PARTS FOR TITAN IIA

- LESS RPIE REQUIRING SPARES
- LESS AGE REQUIRING SPARES
- REDUNDANT USE OF LAUNCH CONTROL AND MONITORING SYSTEMS ALLOWS MORE ECONOMICAL SPARES PROGRAM
- 3 X 1 BASING ALLOWS ECONOMICAL IN-COMPLEX STORAGE OF SPARES FOR HIGH USAGE PARTS
- REDUNDANT USE OF STANDARD PRINTED CIRCUITS REDUCES SPARE PARTS REQUIRED

FIGURE IV-B-6-3

The 3 x 1 basing concepts makes it economical to store high usage parts in the complex. The widespread use of standard, plug-in circuits in the Titan IIA AGE makes the spare part provisioning more accurate and economical.

All of the above factors allow for a more economical and efficient spare parts provisioning program.

d. Personnel Training for Titan IIA (Referende Fig. 6-4) - The training program for Titan IIA will be decidedly more economical than for either Titan I or Titan II. Titan I and Titan II courses currently contain the vast majority of content to be instructed. Only that equipment which is different from that contained in the Titan I complex or the Titan II system need be considered for development of training courses.

The trainers and training equipment currently in USAF inventory will support training on almost all of the Titan IIA system.

The Titan II QQPRI will remain a valid personnel selection criteria if revised to include tasks associated with the modified equipment and complex layout.

In summary, the USAF posture to provide trained personnel for the Titan IIA essentially exists now.

e. Technical Manuals for Titan IIA (Reference Fig. 6-5) - The technical manual program will prove to be another area where costs will be low. The technical data on the Titan I complex facility currently exists and will require primarily the deletion of data on equipment which is to be deactivated. Titan II manuals contain the basic information on Titan IIA equipment. Changes to these manuals will be primarily to reflect the reorientation of the equipment as it will exist in the converted Titan IIA complex. Manuals on unchanged end items of equipment will remain as is. The same will be true of overhaul manuals.

PERSONNEL TRAINING FOR TITAN IIA

- TRAINING COURSES DEVELOPED FOR TITAN II WILL ACCOMPLISH ALMOST ALL TRAINING NEEDED

- TRAINING EQUIPMENT CURRENTLY IN USAF INVENTORY WILL SUPPORT TRAINING

- TITAN II PERSONNEL SELECTION CRITERIA (QQPRI) WILL SUPPORT USAF SELECTION PROGRAM

FIGURE IV-B-6-4

Due to the extensive deactivation of RPIE, manuals on RPIE systems will require revision to detail their new configuration. This revision will be mainly a deletion process rather than a data generation process.

The total technical manual program will be primarily a reorientation of existing data to describe the converted system. The research and analysis of design information and the high costs of this process will not be required in this program.

TECHNICAL MANUALS FOR TITAN IIA

- MOST EQUIPMENT (END ITEM) MANUALS NEED NO REVISION
- MOST SYSTEM MANUALS REQUIRE ONLY REVISION
- NEW FACILITY (RPIE) SYSTEM MANUALS REQUIRED
- MOST OVERHAUL MANUALS REQUIRE NO CHANGE
- NEW CHECK LIST REQUIRED

Figure IX B-6-5
Δa

~~[illegible]~~

V. **Program Plan** - The R&D and production is similar to the Titan IIA development program. The important differences in the two programs are as follows:

A. The operational system verification firings will be conducted out of two launchers of the modified TF-1 facility. The conversion and activation program is shown in the accompanying schedules.

B. The operational base conversion program is somewhat longer in that the changes between the Titan I Weapon System are more extensive then that between the Titan II and IIA Weapon System. The program for accomplishing these conversions is shown in the accompanying schedules. It should also be noted that 50% of the Titan I force is out of EWO for a period of 6 months to expedite conversion. Other modification sequences can be performed to meet typical force maintenance requirements.