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DEVELOPMENT OF NOISE CONTROL FOR SECONDARY AND TERTIARY CRUSHERS IN SURFACE NON-COAL MINING PLANTS AND MILLS

Prepared for:

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

By:

AEROPHYSICS COMPANY

3500 Connecticut Avenue, Northwest
Washington, D. C. 20008

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16. Abstract The purpose of this program is to demonstrate the feasibility and practicality of noise control for secondary and tertiary crushers in surface non-coal mining plants and mills. It is a part of the broad Bureau of Mines program to reduce noise in mines to levels mandated in the Coal Mine Health and Safety Act.

Utilizing the results of previous contractual research efforts in which noise levels of secondary crushers had been measured, two noise enclosures were designed and evaluated for the REXNORD Symons 7-ft diameter secondary and tertiary crushers installed at the Jackson County Iron Company, in Black River Falls, Wisconsin. The first enclosure had a circular shape following closely that of the crusher and was built up entirely of quick-release panels which can be handled by the crusher operator alone. The second enclosure was octogonal in shape and can be rapidly removed, partially or totally using an overhead crane. Both enclosures fully satisfy the noise reduction objectives and permit daily and long-term maintenance of the crushers. Cost analyses show the cost of the enclosure to be less than 10 per cent of the cost of the crusher, the cost of the octagonal enclosure being estimated at only 60 percent of that of the circular one, e. g. $15,000 against $25,000.

It is concluded that the octogonal enclosure best meets the needs of the Jackson County Mining Company and it is recommended that an experimental enclosure be built at the earliest possible time, as proof-of-concept.

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FOREWORD

This report was prepared by Aerophysics Company under USBM Contract Number JO 377 002. The contract was initiated under the Metal and Non-Metal Health and Safety Act Research Program. It was administered under the technical direction of SMRC with Dr. H. K. Sacks acting as the Technical Project Officer. Mrs. D. J. Merriner was the Contract Administrator for the Bureau of Mines.

This final report presents the results of a program to Develop Noise Control For Secondary and Tertiary Crushers in Surface Non-Coal Mining Plants and Mills.

The program was conducted under the technical direction of Dr. Gabriel D. Boehler. Technical assistance was provided by Donald S. Blomquist and Vijay K. Kohli for acoustics and by Leonard J. Munchberg and William F. Foshag for noise control design. Review of the noise control designs for the Symons 7-Foot crusher was provided under subcontract by Rexnord, Inc., the manufacturer of the crusher, under the direction of Vince Matranga. The support of Veneered Metals, Inc., of Edison, New Jersey, in providing material information for the enclosure is gratefully acknowledged.

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EXECUTIVE SUMMARY

The Bureau of Mines is engaged in a broad program to abate noise from underground and surface mining operations as well as associated plants and mills, to bring them into compliance with the provisions of the Metal and Nonmetal Health and Safety Act.

Taconite plants have been identified in particular as having noise exposure in excess of the prescribed maximum. While interim control is provided by ear protection, noise control i a more desirable solution. Through the American Ore Association, the member taconite producers of the United States have offered to cooperate with the Bureau of Mines and its contractors in a study to identify specific noise sources and develop control techniques.

Probably the highest noise sources in taconite plants are the second and third stage crushers. These crushers were therefore identified by the Bureau of Mines as the ideal piece of equipment on which to try advanced techniques of noise control, and two competitive contracts were awarded to Industrial Acoustics Co., Inc. and to Aerophysics Company to propose noise control techniques to significantly reduce the overall noise levels of taconite plant crushers. This report gives the results of the Aerophysics Company design studies for the noise reduction of the 7-ft REX-NORD Symons secondary and/or tertiary crushers installed at the Jackson County Iron Company, in Black River Falls, Wisconsin.

It is the intent of the Bureau of Mines to fund a complete demonstration project for the noise control of crushers in taconite plants to demonstrate the feasibility and practicality (including economic affordability by the industry) of noise reduction. It is therefore intended that one or more of the crushers at Jackson County Iron Company be modified by incorporation of noise control and that the effect of these modification on production and maintenance, if any, be assessed over a fairly long period of time. The results of these tests, rather than the speculative conclusions of the present report, will determine whether or not noise control retrofit of the crusher in the taconite industry is practical.

The Aerophysics Company approach to noise control of Symons crushers is a complete enclosure, preventing the noise to be radiated from the crusher, rather than reducing the noise generated by the crusher itself, which is beyond the state-of-the-art. This enclosure is so designed as not to present a safety hazard or slow down maintenance of the crusher.

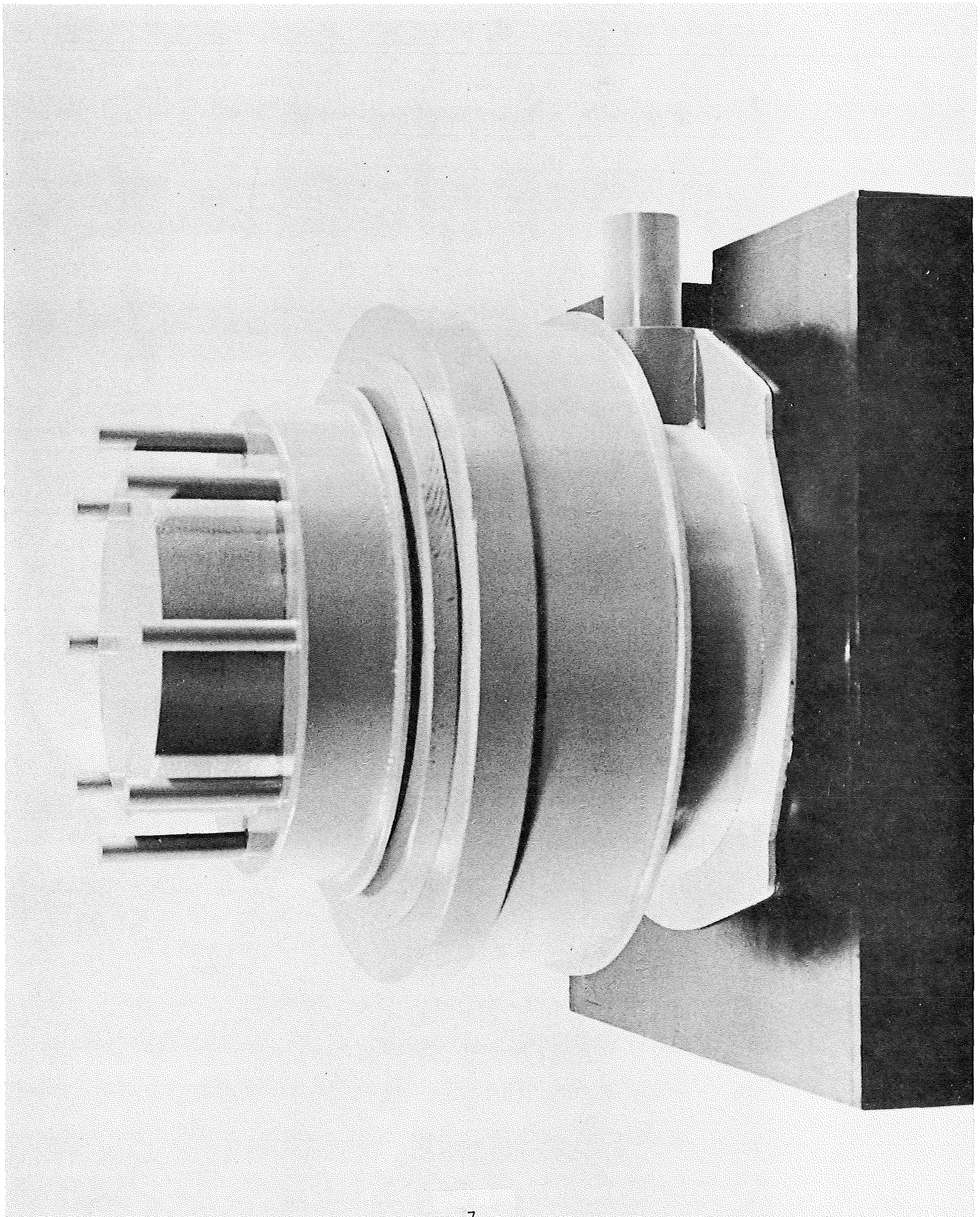
The enclosure consists of a thin skin (less than 1/8-inch thickness), consisting of a metal-lead-metal conposite material, that contains the sound. It may be viewed as a vessel which completely surrounds the crusher, intercepts the radiated airborne noise and is isolated so as not to transmit the structure-borne noise. Two enclosure concepts were successfully studied and are discussed. In the first concept, the enclosure consists of about 50 individual panels, that can be removed either partially or totally. Each panel weights a maximum of 75 pounds and is attached to the neighboring panels by flexible draw quick-release latches. The shape of the enclosure is circular, as the crusher itself, so as to minimize the weight of the enclosure by allowing it to follow the crusher enclosure very closely. In the second concept, straight panels, instead of curved panels, are used. It is found th. the crusher can be completely enclosed using eight standard 8-by-4 ft panels, in an octogonal pattern. Because of the greater weight of this solution, the enclosure must be self-standing, rather than attached to the crusher body. No effort is made then to remove individual panels for maintenance, but four of the eight panels consist entirely of doors, which can be opened and removed for maintenance, as necessary. In addition, crawl space exists between the crusher and the enclosure, for the four panels located between adjacent doors.

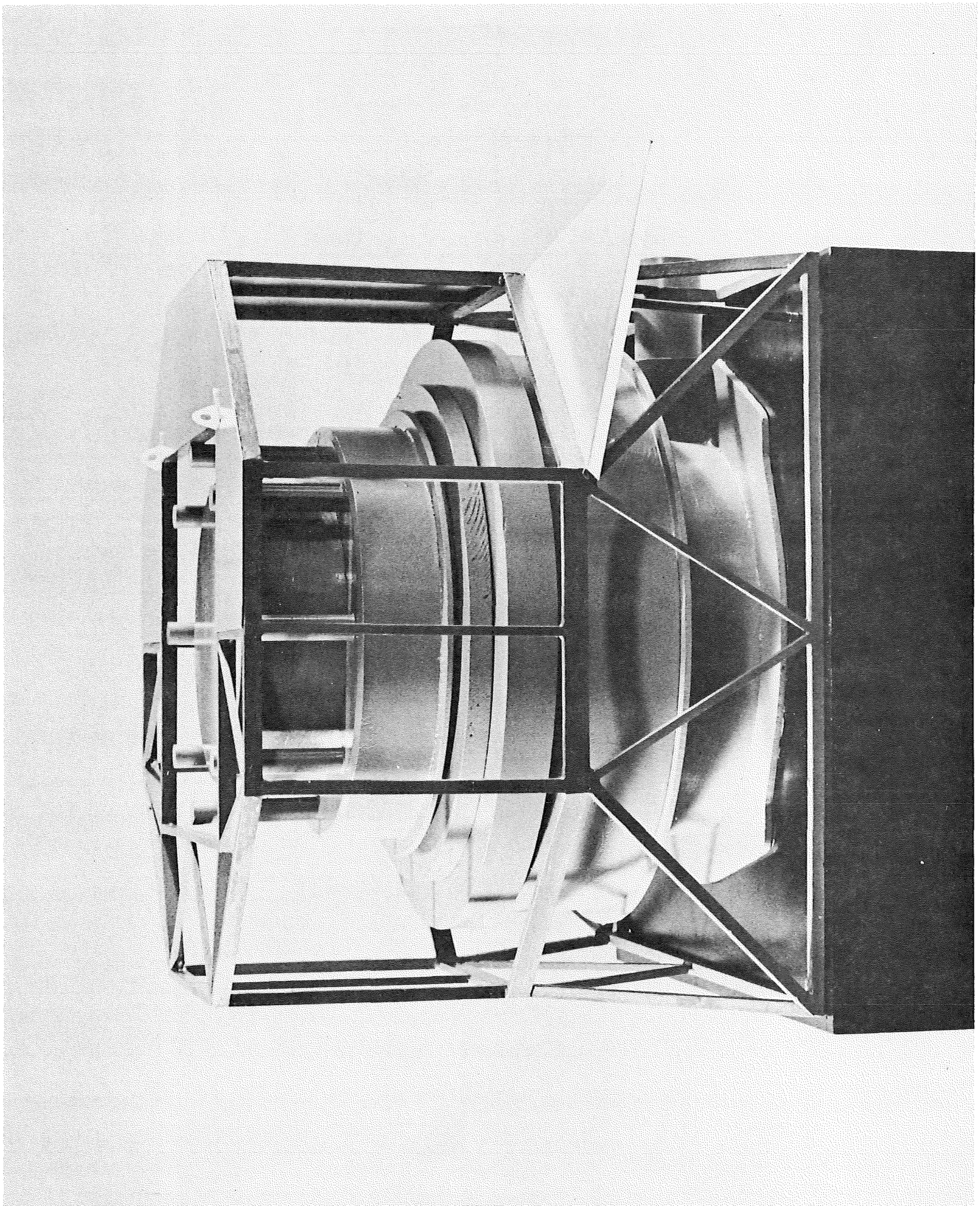
It is concluded that the second design best meets the requirements of the Jackson County Mining Company operation, because an overhead crane is available. The second enclosure is so designed that it can be removed by the overhead crane as a single unit, or one panel at a time. When overhead space is not available, the first design concept may be preferable.

The two design concepts were reviewed under subcontract to Aerophysics Company by REXNORD, the manufacturer of the 7-ft Symons crusher used at Jackson County Iron Company and in the majority of U. S. taconite plants. Both were found to be sound, e. g. not to interfere with the operation and maintenance of the crusher.

Cost analyses were made. It was found that the second concept, using straight instead of curved panels, would be about 40% cheaper than the first. Production costs of $25,000 for the first concept and $15,000 for the second one are estimated. This is 5 to 10% of the cost of the basic crusher, without motor drive. This appears to be an acceptable cost level, if it can be proved that the designs are durable and allow regular maintenance to be performed, without slowing down production.

A 1/10-scale schematic mock-up of the crusher was built and is shown in the accompanying photograph. A scale mockup of the second enclosure concept was also built and is also shown in an accompanying photograph. Please note that the <u>doors</u> have been left out of the mock-up and that





all octagonal rectangular panels, as well as the triangular panels and the top horizontal panels are to be covered by the steel-lead-steel laminate.

It is recommended that the Aerophysics octogonal sound enclosure, shown schematically in the accompanying photograph, be built as soon as possible and installed on one of the three crushers at Jackson County Iron Company, for proof-of-concept. We believe it to be the best solution for the Jackson County plant.

INTRODUCTION

This report is the final report under Contract No. JO 377 002 to the United States Bureau of Mines. It covers Phase III of a project for Noise Control in Surface Non-coal Plants and Mills. The Phase I effort consists of a noise study of taconite mills to determine the magnitude and nature of the noise sources of the various processes. This effort is handled by Donley, Miller and Nowikas, Inc. The Phase II project is concerned with a diagnostic of noise sources in taconite plants, the development of noise control measures, the assessment of the impact of these measures, and the analysis of the arc-air gouger noise problem and is carried out by Bolt, Beranek and Newman, Inc.

This report was written in May, 1977, prior to the publication of either Phase I or Phase II Reports, or even a knowledge of the content of these reports, except in a very general way (Reference 1). However, at the time of finalizing this report, an interim report issued by BBN, Inc., on a Taconite Secondary Crusher Noise Source Diagnostic Study was received. To avoid unnecessary duplication, the material contained in the interim BBN report (Reference 2) is referenced, rather than reproduced herein.

The report successively discusses the background of noise reduction in iron ore processing plants and the method of approach followed by Aerophysics Company in the problem of noise reduction of secondary (and/or tertiary) crushers. Two separate designs for noise enclosures are presented and evaluated; both use sandwich material consisting of cold-roll steel-lead-cold-roll steel. The first design uses a large number of cylindrical panels, each weighing less than 80 pounds; the second design, which was inspired by the particular situation found at the Jackson County Iron Company in Black River Falls, Wisconsin, uses a semi-permanent, octagonal-shaped enclosure with flat panels and large access doors. Both designs are specifically tailored to the Nordberg 7-foot extra heavy-duty crusher. For clarity, preliminary drawings for the two designs are presented in Appendix A and B, respectively. The report concludes with the major recommendation that, since noise control hardware can only be assessed in service use, the second Aerophysics design should be fabricated and installed at the earliest possible date in an ore-beneficiation plant, for proof-of concept.

BACKGROUND ON NOISE CONTROL IN SURFACE NON-COAL PLANTS AND MILLS

Background for the Bureau of Mines Program

The Metal and Nonmetal Health and Safety Act and the rules and regulations promulgated as a result thereof address many aspects of the health and safety of the miner, both in underground and surface mining operations as well as associated plants and mills. One aspect of the health standards concerns noise control; the regulations prescribe a noise exposure criteria as outlined in the Coal Mine Health and Safety Act. Work is underway to abate noise from underground and surface mining operations, some of which can be solved by existing technology and some of which require advancement of the state of the art in noise control relative to the machines and equipment involved. In many mining operations the work cycle is intermittent and, hence, personal exposure is controlled by the amount of work and the location of the personnel relative to the noise source. In many of the mills and ore beneficiation plants, the noise is nominally constant and in many cases the exposure of the worker can be controlled by placing him in an acoustical shelter. However, because of the highly reverberant nature of these facilities, noise levels are essentially constant throughout large portions of the plant and, for personnel who must move throughout the plant, noise exposure in excess of the prescribed maximum is common. While interim control is provided by ear protection, noise control is a more desirable solution; while the problem generally applies to all ore beneficiation plants and mills, one particular type of plant in which the magnitude of the problem has been extensively defined is taconite plants. Because of the nature of the material being processed, the noise levels and the amount of maintenance are perhaps among the highest in this type of facility. Through the American Iron Ore Association, the member taconite producers of the United States have offered to cooperate with the Bureau of Mines in a study to identify specific noise sources and develop control techniques.

The principal noise sources in taconite plants include crushers, particularly second and third stage crusher as well as chutes and screens, filters, and kilns. Additionally, another noisy operation which is extensively used in the maintenance of these facilities is the process of removing metal by a combination of an electric arc and a stream of air known by a variety of trade names of which one, for reference, is Arc-Air. Some types of previously applied noise control may be applicable to the problems identified. However, their durability and suitability to the environment have not been determined. Such facilities are obviously highly capitalized and it is not feasible or reasonable to completely rebuild such an installation. However, by judicious application of noise control techniques, it may be possible to significantly reduce the overall noise levels.

A competitive request for proposal was issued by the Bureau of Mines in the Spring of 1975, as a first step toward accomplishing the objective of noise reduction in ore beneficiation plants. The proposal identifies three phases as follows:

Phase I - Noise Source Identification
Phase II - Diagnostic of Noise Sources and Development of Noise Control
Phase III - Noise Control for Secondary Crushers

In the Fall of 1976, four contracts were awarded as follows:

Phase I - Donley, Miller and Nowidas, Inc.
Phase II - Bolt, Beranek and Newman, Inc.
Phase III-1 - Aerophysics Company and Industrial Acoustics Company, Inc.

Two competitive design study contracts were awarded for Phase III, and an award for Phase III-2, "Demonstration of Noise Control for Secondary Crushers", was deferred, pending completion of the Phase III-1 Studies.

At the time of the writing of the present report, the only issued reports that can be referenced are References 1 and 2.

Technology Background

There has been repeated attempts in the past few years to control noise in iron ore processing plants. In some instances, engineering efforts have been successful, in others they have not. The history of past attempts is summarized in Reference 3, which is the starting point of the present investigation. Referring mostly to the crusher area of the taconite plants, the author states:

" In conclusion, we have not found any feasible engineering or administrative solution to the major problem of the high noise levels in either taconite or natural ore crushing plants. Meetings with manufacturers of plant equipment have been held to determine what they can do with their machine design to reduce noise levels. Further research is needed to be able to develop methods of isolating noise at the source. Work is being done with equipment manufacturers to build noise control into their products and this would permit new plant construction with lower noise levels. If these sound packages are developed for new equipment, it would hopefully be possible to retrofit some of the old equipment with a similar noise control package.

We urge that the noise control problems in taconite or natural ore processing plants be approached cautiously and on a sound basis. We do not want to expose our employees to additional safety hazard because we do have an effective hearing protection program which adequately protects the employee. We want to make accurate judgments based on competent engineering and adequate test work before making any changes in these plants. "

The preceding statements would seem to indicate that the proper noise reduction technology is not on hand to reduce the high noise levels in iron ore processing plants. We interpret the statement as a thoughtful warning that this is a difficult problem which must be approached "cautiously and on a sound basis". However, there is a variety of techniques and materials that can be used for "isolating noise at the source". The difficulty is that an engineering solution must not decrease the efficiency of the plant, complicate maintenance or create additional safety hazards. Finally, plant retrofit must be accomplished at a reasonable cost. Willing acceptance of the retrofit by plant operating personnel and management is an integral part of technical feasibility. In this light, then, one has very few examples of prior sucessful efforts of this type and the project discussed here is of a pioneering nature. The approach is then to attack one problem at a time. The problem studied here is the noise reduction of the Symons crusher, shown on Figures 1 to 4 which follow , at the exclusion of either the feed chute ahead of it or the screens downstream of it. The reason why the crusher is chosen for noise treatment is that it is the largest single noise source in a taconite plant.

In final analysis, the technical feasibility of reducing noise in taconite plants must be viewed in economic terms, e.g., by assessing the cost of the engineering solution to the noise problem in relation to the total cost of operating the plant. If this cost is judged excessive by the operator, then it must be concluded that engineering feasibility is not there.

Technical feasibility must also be judged in terms of acceptance by the operator. Should an economical, effective noise control system be developed, it would have to be considered technically unfit if it did not gain acceptance by the mining mill operator.

METHOD OF APPROACH

Noise control in taconite plants can be approached either from an administrative or from an engineering standpoint. The approach of this contract is a purely engineering approach.

In accordance with the terms of the Statement of Work, the project consists of the following three steps:

- Transfer of Information
- Noise Level Measurements and Crusher Inspection
- Design of Noise Control System

These three steps are discussed below:

Transfer of Information

As discussed earlier, this report is concerned with Phase III of a project, in which all three phases are handled by different contractors. Scheduling problems occurred, such as the final report prepared by the Phase II contractor, which was to have been reviewed by Aerophysics Company at the start of this effort, was not available in time. Aerophysics Company was, therefore, directed to proceed with the design of its crusher noise control system without any interfacing with the Phase II contractor. Since Aerophysics Company had prior experience in noise reduction and had a specific approach in mind, on the strength of which it had been awarded this contract, the lack of background information from the Phase II contractor did not hamper or slow down its effort.

Noise Level Measurements and Crusher Inspection

The secondary crusher chosen by the Bureau of Mines for study is located at the Jackson County Iron Company, in Black River Falls, Wisconsin. Aerophysics Company sent personnel on several occasions to the Jackson County plant to familiarize itself with the installation and obtain first-hand information on operating and maintenance problems. In addition, Aerophysics worked closely with personnel of the Crusher Department of the Nordberg Machinery Group of REXNORD, the manufacturer of the crushers. Through visits at the Rexnord plant, in Milwaukee, Wisconsin, and discussions with Rexnord personnel, a thorough familiarity with the Rexnord's Symons crushers, both past and current designs, was acquired.

As far as noise level measurements of the secondary crusher are concerned, it turned out that similar measurements had been scheduled as part of the Phase II effort. It was decided to combine the required Phase II and Phase III measurements into a single series, to be performed by the Phase II contractor, Bolt, Beranek and Newman, Inc., with the assistance of an Aerophysics sound engineer, V. K. Kohli. A thorough review of the requirements for data was made by Aerophysics and presented to BBN, Inc., at a meeting held at the Bureau of Mines on 19 January 1977.

Measurements were made on February 1 and 2, 1977, by BBN, Inc., at Jackson County and are reported in Reference 2. The results of Reference 2 are exhaustive and should represent the authoritative source of information on the Noise Source Diagnostic of Crushers for many years to come. The noise data used for the Aerophysics analysis are taken from Reference 2, which is then an essential adjunct to this report.

One of the problems that Aerophysics had to address was the ability to measure the noise reduction achieved on the secondary crusher after installation of the noise control device, to demonstrate the effectiveness of this device. Current plans are to initially demonstrate noise control on only one crusher at the Jackson County Mine Company. It cannot be expected that the ambient noise level in the plant will be decreased as a result of controlling one crusher only, nor is it practical to shut down the whole plant, except that one crusher, to measure noise on the crusher before and after. The straight-forward solution is then to make close-field noise measurements at chosen locations around the crusher before and after noise treatment. At the meeting held at the Bureau of Mines on 19 January 1977, agreement was reached as to where to make the measurements and a target for noise measurements. The chosen microphone locations are shown on Figure 1.2 of Reference 2 for the drive level and on Figure 1.3 for the adjustment level. The corresponding noise data, the "before" data, correspond to Tests 2 to 5 of Reference 2.

The goal of a 10 dB noise reduction was established, with a $\pm$1.5 dB accuracy.

Design of Noise Control System

In January, 1977, a preliminary design of an Aerophysics-proposed noise enclosure for the Symons crushers was prepared. This design was discussed with Jackson County Iron Company personnel on 1 February 1977, and with Rexnord personnel on 2 February 1977, and found generally suitable. During February, this design was developed in greater detail and resubmitted to Jackson County personnel on 2 March 1977. Objections about safety aspects of the design and its maintainability were raised. Further insights into the Jackson County requirements were gained, and a second design evolved as a result. Feasibility of the second approach was ascertained through a partial full-scale mock-up which was constructed around the crusher on 3 and 4 March 1977. The second design was perfected during March, 1977. To facilitate visualization of the second design, a 1/10-scale wooden mock-up of the 7-Foot Symons Crusher and of the proposed sound enclosure was built.

Both Aerophysics designs are discussed in detail in the next section. Reduced copies of the drawings of the two designs are included as Appendix A and Appendix B, respectively.

DISCUSSION OF TWO PROPOSED DESIGNS FOR THE NOISE CONTROL OF SECONDARY CRUSHERS

Description of the Symons 7-Foot Crusher

The Symons cone crusher, manufactured by Rexnord, is used in the majority of taconite plants as secondary and tertiary crusher and, therefore, a design which controls the noise of that particular piece of equipment will have a very wide use in taconite plants. Rexnord has published a very complete instruction manual for the unit, which is in the hands of all operators (Reference 4).

A picture of a typical uninstalled Symons cone crusher is shown in Figure 1. The installed 7-foot secondary crusher at Jackson County Iron Company is best described by means of three photos, Figures 2 to 4. Figure 2 shows an overall view, with the three levels: drive level, adjustment level, and feed chute level. Note that, in this particular installation, there is no integral feed platform. The feed platform is structurally isolated from the crusher's main frame. The rock is guided into the crusher inlet by a 1/4-inch rubber boot, which is more clearly shown in Figure 3. Should rock get jammed inside the crusher, it will spill over through the boot and collect on the adjustment level until the operator has a chance to stop the rock feed. Continuous monitoring of the equipment is therefore essential. The adjustment level is shown in more detail in Figure 3. The drive level is shown in the forefront of Figure 4. The two tertiary crushers are shown in the background of Figure 4. A photograph of the upper level of one of the two tertiary crushers is shown in Figure 5. A more general view of the two tertiary crushers is shown in Figure 6.

From the above photographs and study of the installation, the following remarks can be made:

(1) Symons secondary and tertiary crushers are generally alike in outside dimensions and appearance. A difference is that the secondary crusher has a standard head and the tertiary crusher a short head.

(2) The 7-foot Symons crusher is very widely used in the taconite industry and its outside shape has not changed much in the last 20 years. However, installation details are practically different at every site. The above photographs show clearly the differences between feed chutes of the secondary and tertiary crushers at Jackson County Iron Company. Also, from plant to plant, one finds differences in foundations, feed, and discharge arrangements.

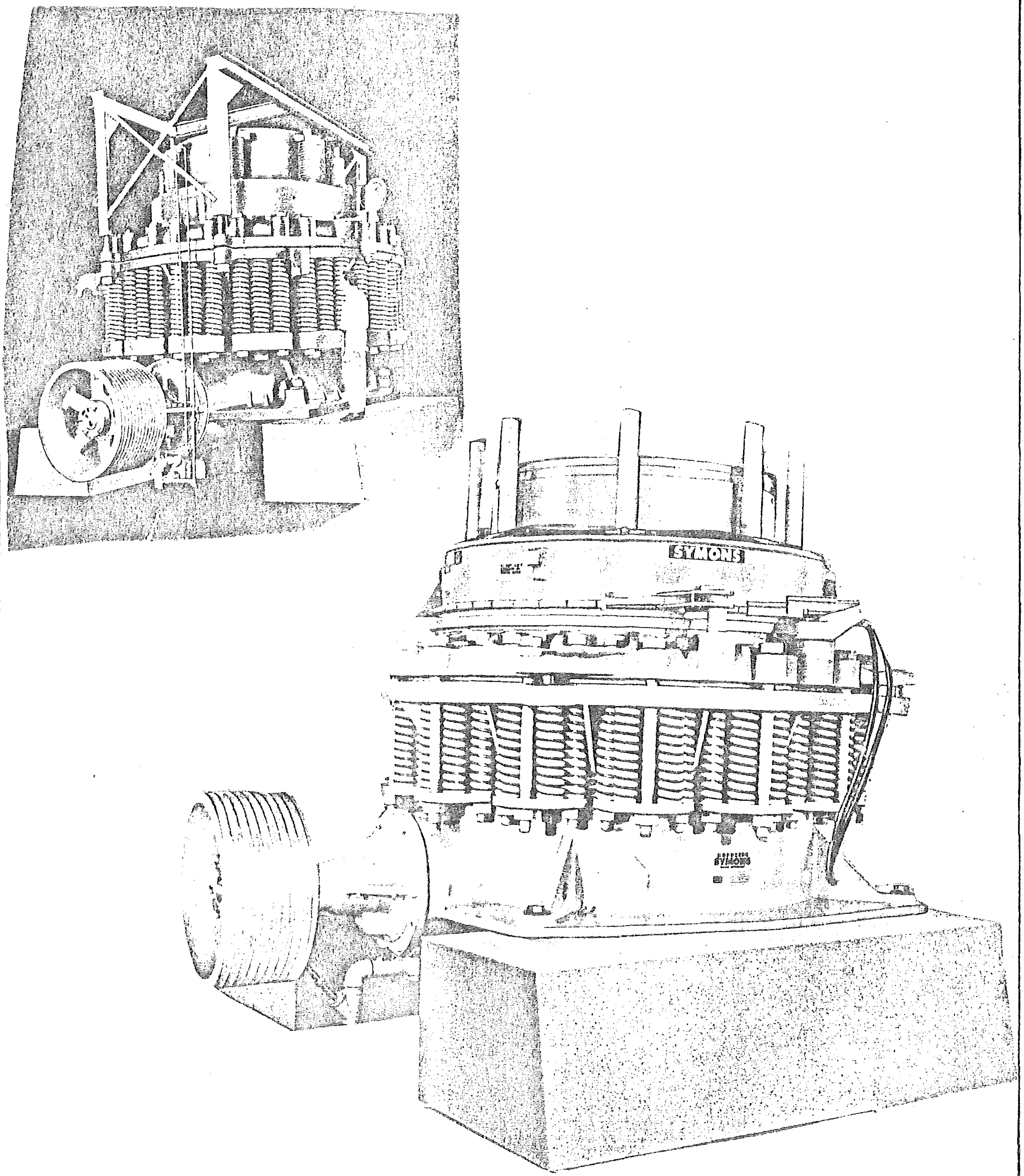


FIGURE 1: Typical Symons Cone Crusher with and without feed platform.

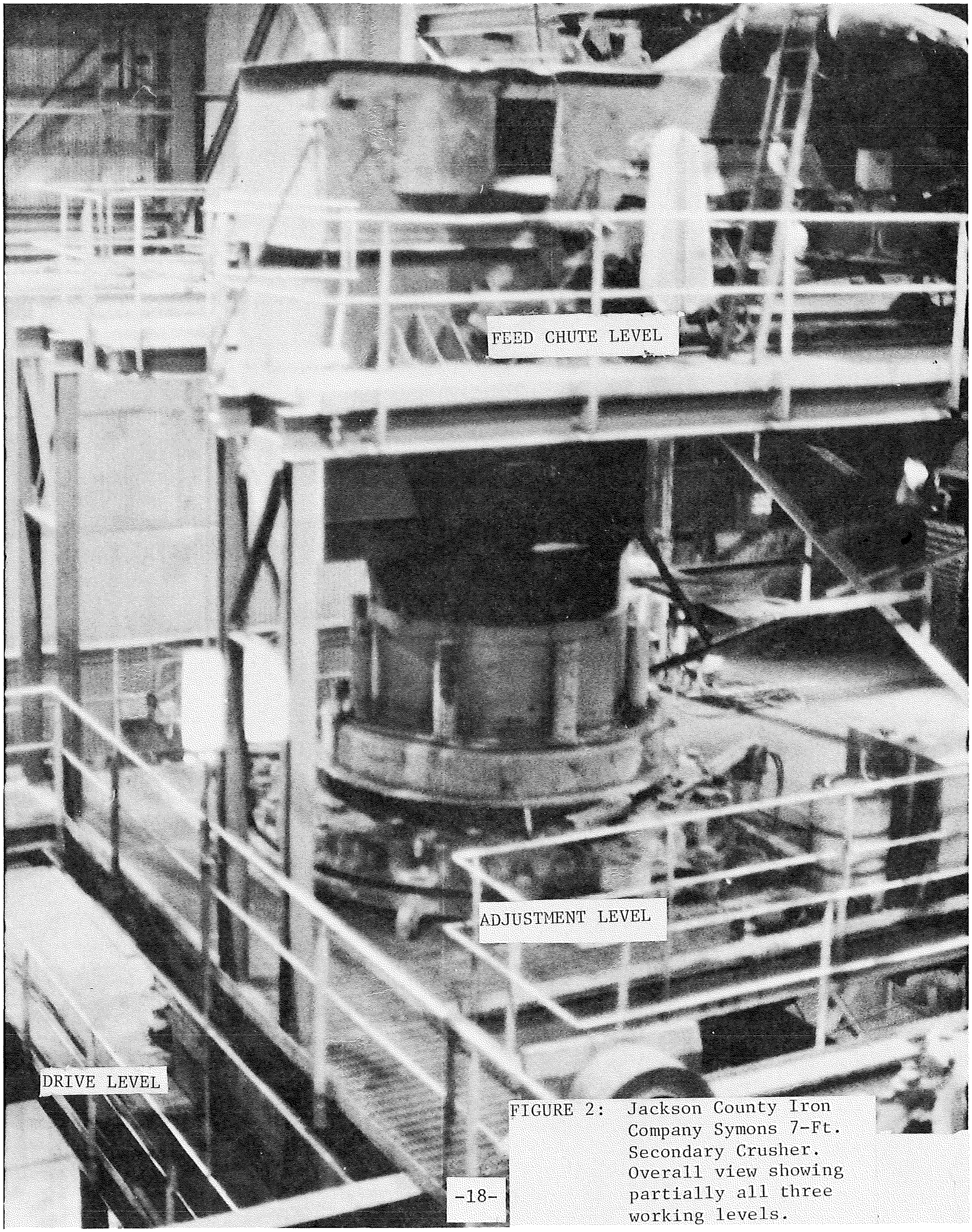


FIGURE 2: Jackson County Iron Company Symons 7-Ft. Secondary Crusher. Overall view showing partially all three working levels.

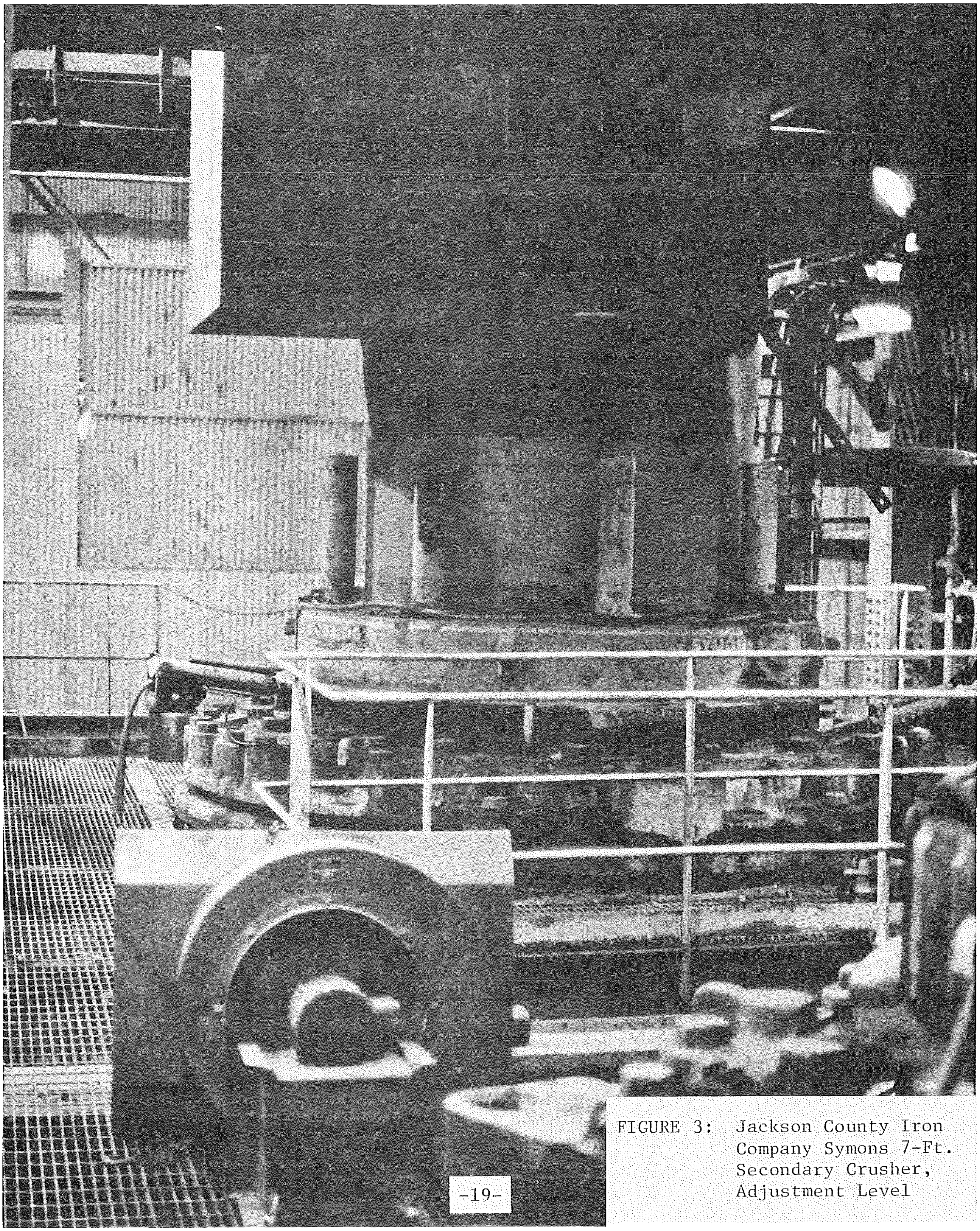


FIGURE 3: Jackson County Iron Company Symons 7-Ft. Secondary Crusher, Adjustment Level

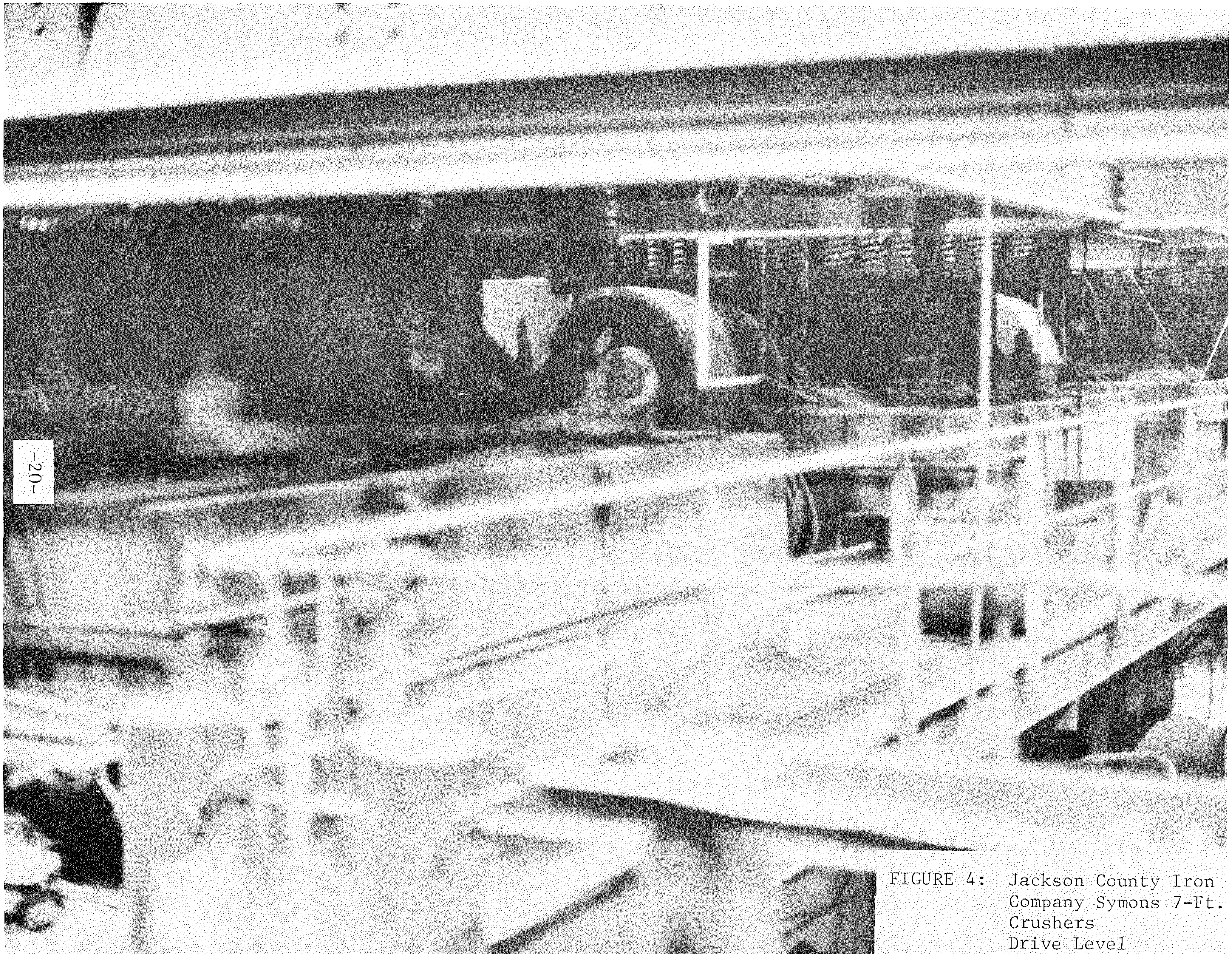


FIGURE 4: Jackson County Iron Company Symons 7-Ft. Crushers Drive Level

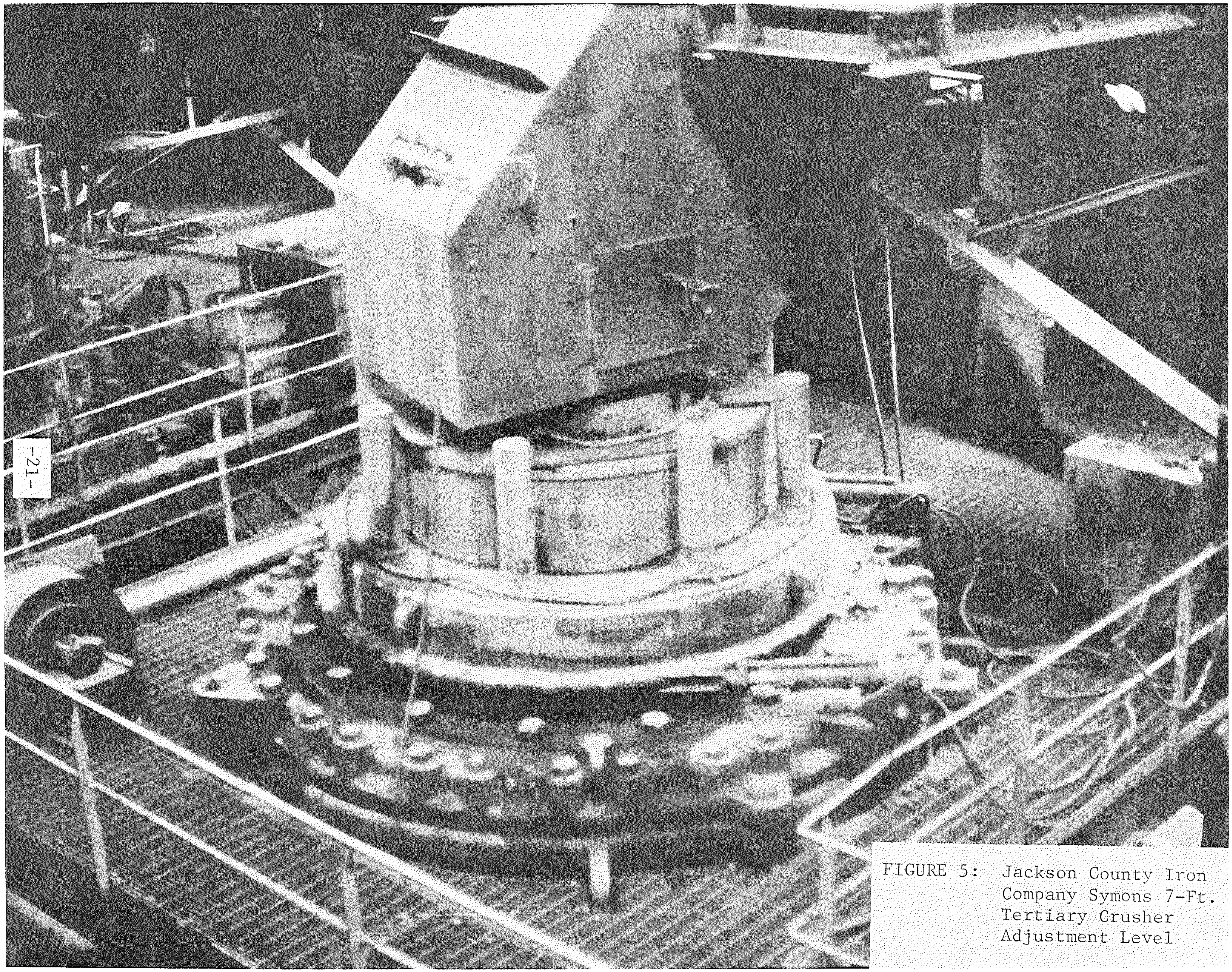


FIGURE 5: Jackson County Iron Company Symons 7-Ft. Tertiary Crusher Adjustment Level

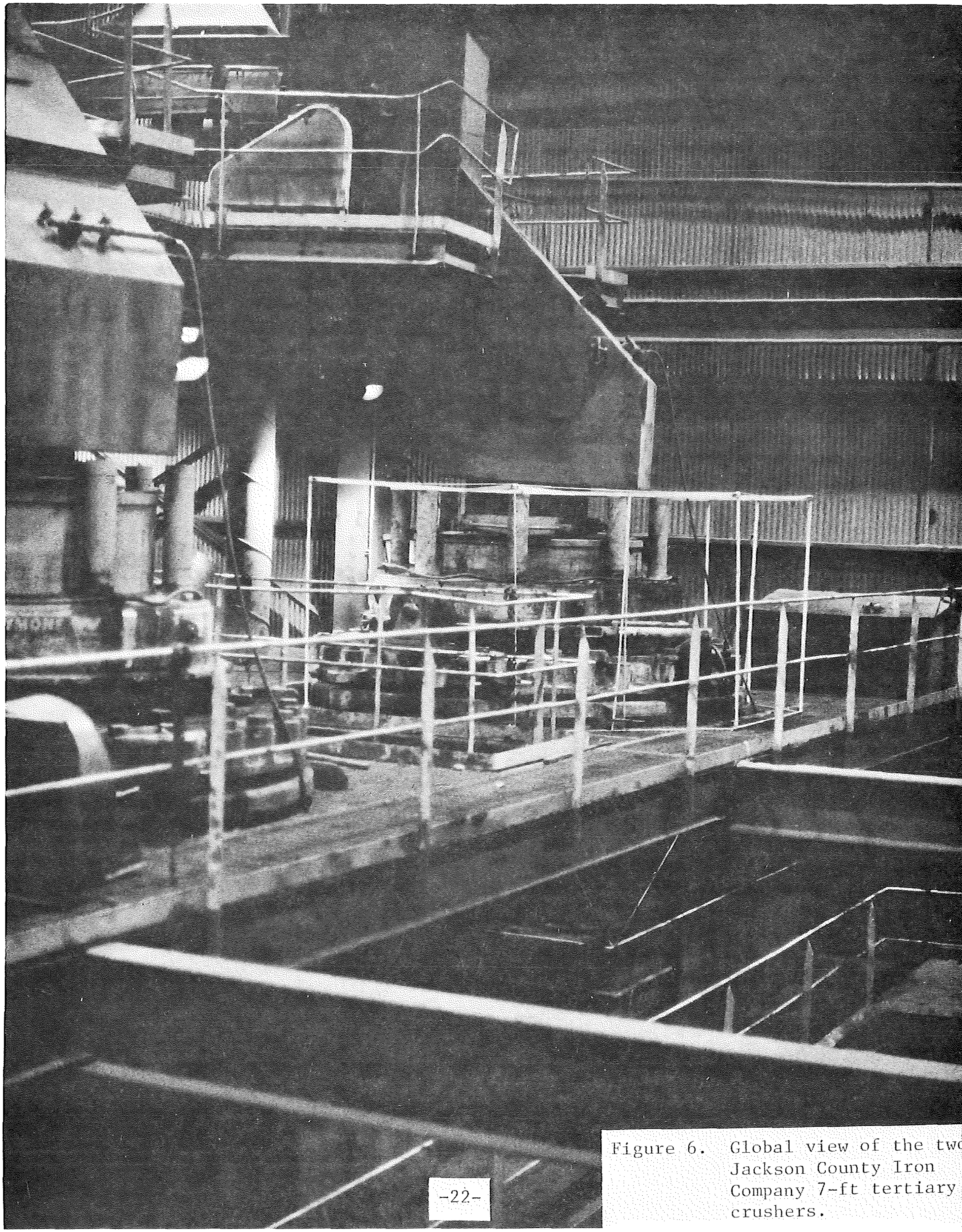


Figure 6. Global view of the two Jackson County Iron Company 7-ft tertiary crushers.

Operation and Maintenance of Symons Crushers

An understanding of the operation and maintenance of the Symons Cone Crusher is a prerequisite to the design of a noise enclosure of the crusher, since the enclosure must not interfere with crushing production efficiency and the maintenance schedule. Aerophysics' understanding of the problem was gained through several visits to the Rexnord plant, discussions with Rexnord personnel, discussions with operations and maintenance personnel at Jackson County Iron Company and a detailed study of the 7-foot crusher drawings. In addition, the two designs described in the following pages were reviewed, under a consulting agreement, by Rexnord design personnel.

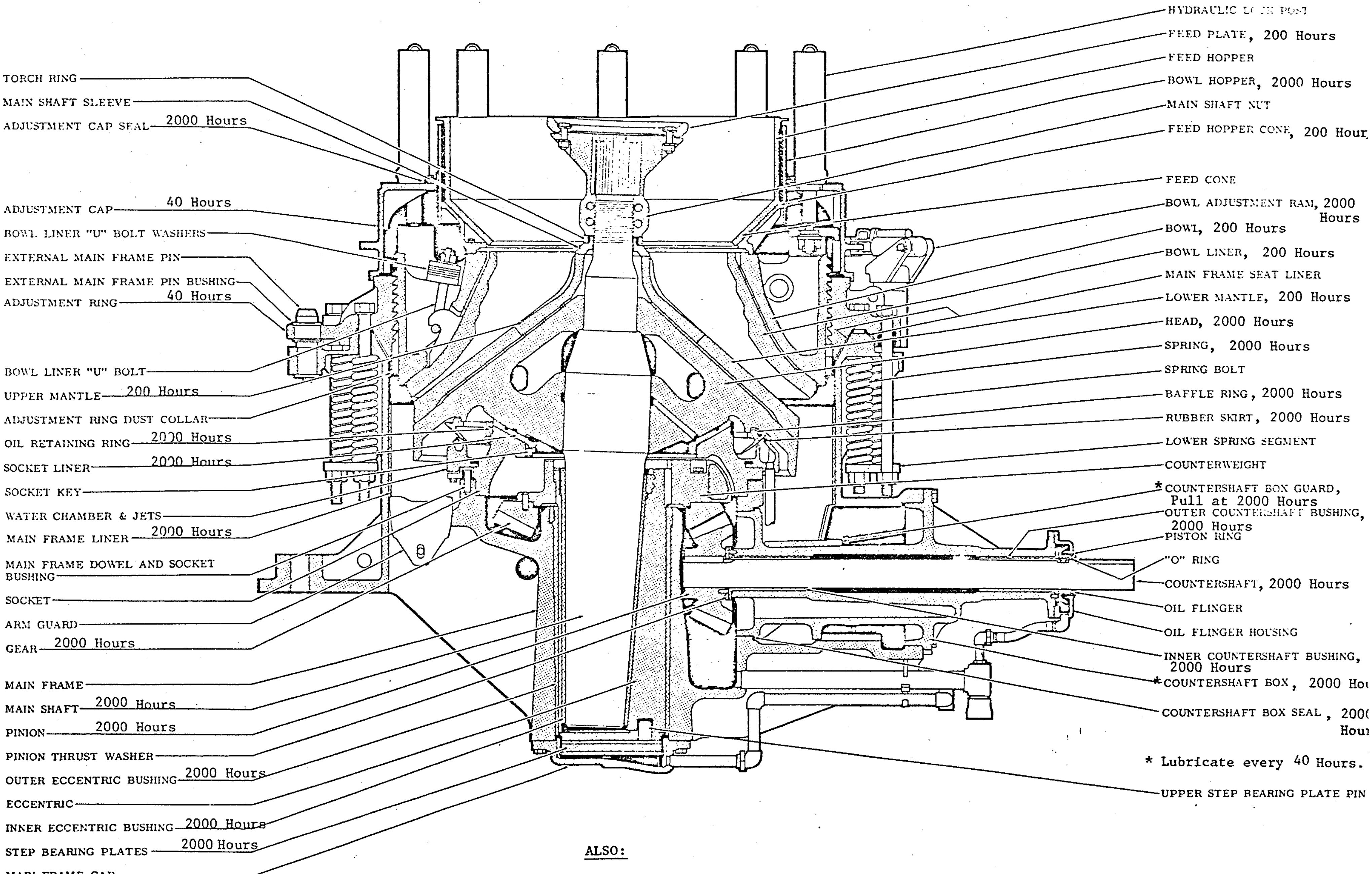
The operation referred to here corresponds essentially to that observed at the Jackson County Iron Company and is typical of iron ore crushing plants; however, some differences may occur from mine to mine. In particular, the total operating time of the secondary and tertiary crushers may vary. In principle, with a good supply of ore, the Jackson County secondary crusher can deliver the plant's output of 800,000 Tons of iron ore per year in 10 shifts a week. During 1977, because of problems with the ore, up to twice as many shifts were needed. Because of the unpredictability of the needs, and of the fact that other plants may have higher use rates, the crushers must be able to operate 24 hours a day.

A cut section of the Symons 7-foot standard heavy-duty crusher is shown as Figure 7. Intervals between servicing for each component (according to Reference 4) are shown on the figure. Additional discussion is made below.

..Crusher operation requires continuous monitoring. No operating crusher is ever left unattended. Jamming of the rock may occur at any time and will result in a rock slide outside the crusher if immediate corrective action is not taken. Jamming may be due to tramp iron, and the installation of metal detectors ahead of the crusher has done much to reduce its occurrence. However, wet ore may also pack the crusher and jam it. Whenever the drive motor stops accidentally, the crusher jams. Jamming is unpredictable--it may happen several times a week and then not for several months. When it happens, easy access to the crusher is essential for unjamming. Unjamming is done in a number of ways, by burning with a torch in case of tramp iron, from the top or the bottom, or releasing the jaws with a 50-Ton jack.

..The hydraulic rams (shown for example on Figures 3 and 5) must be very easily accessible, since they are advanced one notch per shift. Hydraulic controls are located in a console located in a corner of the adjustment platform. The console operator must be able to see the ram when it is being advanced, as a matter of safety.

..Access to the adjustment cap must be easy, since the cap is removed quite often (say, every two weeks, or so).



ALSO:

- Advance adjustment cap one notch per shift
- Lubricate lower discharge every 24 hours

FIGURE 7: Typical Maintenance Schedu on 7-Foot Standard Heavy-Duty Symons Crusher

..The lower mantle is removed at Jackson County every three or four months for the secondary crusher, every six months for the tertiary crushers. Removal is by means of the overhead crane with the feed chute being slided back on rails. Sofar, the main frame of the crushers never had to be removed since the start of the Jackson County plant. However, when the mantle is removed, the motor deck must be clear of any obstructions.

..There is an access door to the discharge end of the crusher in the concrete base. When wet ore is used, access may be required as often as three or four times a week.

..Hydraulic lines feed to both the rams and the lock posts. There are occasional hydraulic leaks, requiring easy access to the lines.

..The bowl screws must be greased through peripheral grease fittings, in principle at least every 40 hours.

..The shaft may have to be replaced occasionally and, therefore, must be relatively easy to pull out.

Discussion of the Noise Reduction Concept

To control the noise of the secondary or tertiary crushers, two methods are available in principle: Either reduce the noise at the source or to isolate the operator from the noise source through a physical barrier. If the barrier completely surrounds the noise source, it becomes an enclosure.

Of these approaches, the first one must be rejected outright. The reason is that, as a result of recent work on crusher noise source identification by the United States Steel and Rexnord (Reference 3) and by BBN, Inc., (Reference 2), it is known that the major source of noise is the crushing operation itself. Therefore, there is no way, short of a major crusher redesign program to reduce the crusher noise.

The second approach is practical in the form of a complete enclosure. This enclosure must include the sides and the top of the crusher, since the bottom is a heavy concrete base through which a negligible amount of noise is propagated. In the Aerophysics' concept, the enclosure consists of a thin "skin" placed as close to the crusher body as possible (on the sides and the top, outside the chute), to minimize its weight. However, that "skin" must be an independent structure, physically and vibrationally independent of the crusher walls, i.e., located a few inches from the wall. It may be viewed as a vessel which completely surrounds the crusher and intercepts the radiated airborne noise. In addition, being vibrationally isolated from the crusher, no structure-borne noise is carried out.

To satisfy the accessibility requirements to the crusher discussed before, the "skin" must be, in some way, easily removable; either because it consists of cowling-type panels, or because it incorporates hinged doors or sliding panels. To make possible a thin enclosure, a bonded sandwich material is used, consisting of an outer skin of cold-rolled steel, a lead metal core and a cold-rolled steel inner "skin".

This concept is implemented below and two different designs are presently with the second one being recommended for application to the Jackson County Iron Company crushers. Because both designs use the same sandwich material, a discussion is first made of the choice of this material.

Determination of the Enclosure Material Characteristics

The determination of the characteristics of the enclosure material can be made independently of the geometry and of the detailed design of the enclosure, since it depends only upon the noise source (the Symons crusher) and the desired noise reduction. Only airborne noise is considered, since it is assumed that the enclosure is vibrationally isolated from the crusher's body.

The enclosure is built of a constrained layer material which consists of a sandwich sheet, in the form of a steel-lead-steel laminate. The steel provides two durable surfaces, both inside and outside. The lead provides the noise barrier. Perforated panels were investigated and rejected because of the heavy-dust environment in the crusher area, and that altogether it would have led to another concept.

The possibility of using a single-metal sheet enclosure was also investigated. Using the crusher noise source data reported by BBN, Inc. in Figure 4.1.1 of Reference 3, the expected attenuation, using an enclosure constructed of 10-gauge sheet metal, was calculated. The calculations used the 1/3 octave levels rather than the less certain 1 octave levels. They take into account the fact that the acoustic wave will no longer be normal to the surface of the crusher, since the field will become quite reverberent with the addition of the enclosure. It was assumed for the calculations that the acoustic wave will vary between 0 and 87 degrees. The results of the calculations show that the expected attenuation would result in an A-weighted level of 91 dB. This high level is mainly due to the coincidence dip of the plate at 3.65k Hertz. The single-sheet metal approach was therefore rejected.

The sandwich sheet that was selected is described on the next page. Steel and lead are adhesively bonded together using, for example, the CY BOND 4000 Adhesive (CY BOND is a trade mark of American Cyanamid Company.).

MATERIAL	THICKNESS	WEIGHT (lb/ft^2)
CRS 16 Gauge	.0598"	2.50
Lead Sheet	.032"	2.00
CRS 26 Gauge	.0179"	0.75
	Σt = .1097"	ΣW = 5.25 lb/ft^2

Results of calculations of the noise attenuation created by the enclosure material shown above, for the crusher noise source shown in Figure 4.1.1 of Reference 2, are shown in the third column of Figure 8. Similar results, assuming that the enclosure would consist of a 0.032-inch thick lead sheet alone, are shown in column 4 of Figure 8.

Finally, for the rubber apron at the top of the crusher (Figure 3), attenuation calculations were made by using a limp mass law for rubber with a durometer hardness, Shore A, of 30 (specific gravity of 1.01) and a thickness of 1/4 inch. Results are shown in column 5 of Figure 8.

The A-weight levels for the three cases are shown also on Figure 8. One adds 5 dB to the A-weights to account for the reverberating field.

It is expected that the true maximum levels outside the crusher enclosure will fall somewhere between the calculations for the sandwich material (column 3), i.e., 72 dB(A) and those for the lead alone (column 4), i.e., 81 dB(A) [This is because of the coincidence dip in the metal sheet.] We predict, therefore, for the proposed enclosure a maximum sound pressure level around 76 dB(A).

OCTAVE BAND CENTER FREQUENCY HERTZ	SOUND PRESSURE LEVELS OF CRUSHER FIG. 4.1.1 OF REF. 3	SOUND PRESSURE LEVEL AFTER ATTENUATION DUE TO SANDWICH MATERIAL, CRS 16 - 0.032 LEAD - CRS 26	SOUND PRESSURE LEVEL AFTER ATTENUATION DUE TO 0.032-INCH LEAD SHEET ALONE	SOUND PRESSURE LEVEL AFTER ATTENUATION DUE TO 1/4-INCH RUBBER APRON
63	95	51	61	63
125	98	58	68	70
250	102	64	73	76
500	101	62	72	74
1000	97	56	65	68
2000	90	44	53	56
4000	84	31	41	44
A-WEIGHT	--	67	76	79
A-WEIGHT PLUS REVERBERATING FIELD	--	72	81	84

FIGURE 8: Results of Calculations of Sound Pressure Attenuation Due to Three Types of Enclosures

Discussion of the First Proposed Noise Control Design (Round Shape)

As explained earlier, the concept which led to the first design was to completely surround the crusher body with a thin "skin" enclosure (less then 1/8-inch thick). Since the crusher is circular in shape, this led to a cylindrical enclosure, except for the lower section. Obviously, the bottom part of the enclosure can rest on the crusher's concrete foundation, but a thin enclosure will not support its own weight over a height of more than ten feet. In the first design, the intermediate sections of the enclosures are, therefore, partially supported and steadied by direct attachment to the crusher body through a shear mount which provides the proper isolation from structure-borne noise. The top part of the enclosure is supported from the upper level. In addition, the enclosure must be quickly removable, partially or totally, which leads to a series of individual panels fastened to one another by quick-release clamps. The panels must be light enough so that they can usually be handled by a single crusher attendant.

The design is shown in the eight (8) drawing sheets reproduced in Appendix A which follows and in the three drawings of Appendix B (Drawings SK72-104, Page B-11 and SK72-105, Sheet 1, Page B-12 and Sheet 2, Page B-13).

(1) Details of the Drawings

The general view of the crusher enclosure is shown on Sheet 1 of Drawing SK72-001, Page A-2. It is seen that the enclosure consists of, roughly, 50 acoustic panels, as follows--starting from the bottom:

..One acoustic panel to cover the door opening, on the east side of the crusher concrete foundation, which gives access to the bottom of the crusher (Drawing SK72-104, Page B-11).

..One acoustic panel to cover the countershaft opening, on the north side of the crusher foundation (Drawings SK72-104, Page B-11, SK72-105, Sheets 1 and 2, Pages B-12, -13).

..Four semi-detachable rectangular panels, which cover the lower 27-1/2 inches of the enclosure and sit directly on the concrete base (Drawing SK72-002, Page A-5). These panels must be rectangular, rather than cylindrical, to facilitate the junction with the countershaft and because of flanges in the crusher's lower body. Note that these panels overhang the concrete foundation on the north side and, therefore, that a small horizontal acoustic panel extending the base surface outward must be added there.

..At the elevation 27-1/2 inches above the concrete base, four (or two as desired) horizontal panels make the transition between the square and the circular planform shape of the enclosure (Drawing SK72-102, Page A-5).

..Three rings of straight cylindrical acoustic panels, stacked on top of the rectangular acoustical panels. Each ring is sliced into eight pieces, obtained by dividing the circumference into eight equal 60-degree sectors, for a total of 24 panels. The lower and upper rings have a constant diameter (Drawing SK72-003, Sheet 1, Page A-6; the lower ring corresponds to Part No. -1, at the radius of 88 inches from the center; the upper ring corresponds to Part No. -2, at a radius of 92 inches.). The intermediate ring provides the step between the 88 inches and the 92-inch radius (Drawing SK72-003, Sheet 2, Page A-7).

..Two rings of conical panels, also slice into eight equal and interchangeable panels (Drawing SK72-003, Sheet 3, Page A-8 and Sheet 4, Page A-9), for a total of 16 panels.

(2) Acoustic Enclosure Panel Support

..The lower rectangular panels rest directly on the concrete base. Care must be exercised that the junction between the base and the panels be acoustically sealed, as shown schematically in Detail 1 of Drawing SK72-002, Page A-5.

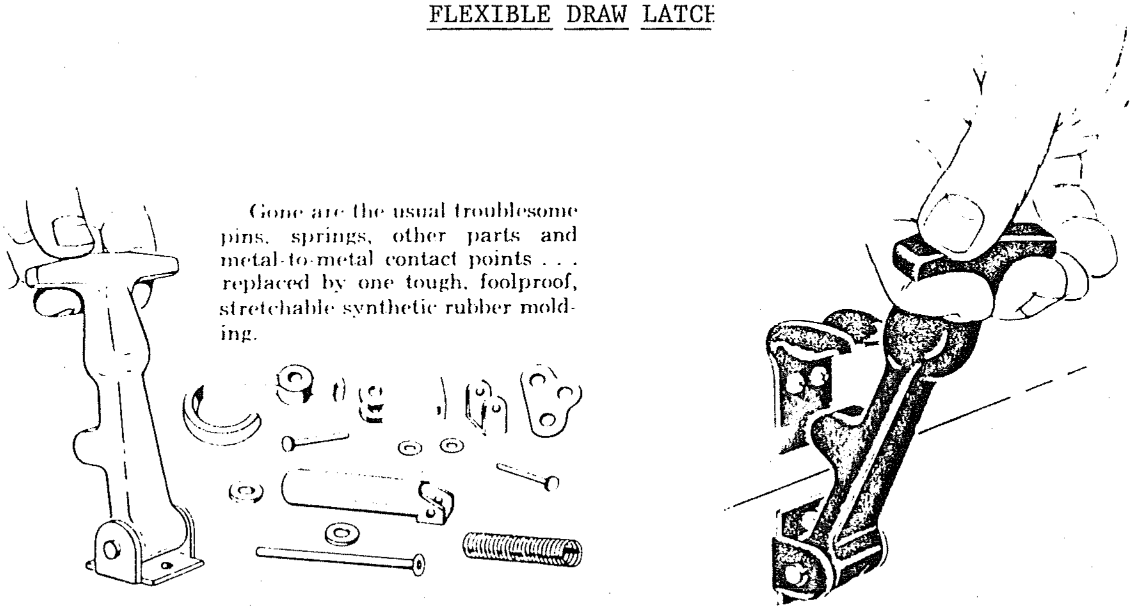
..The intermediate panels are stacked on top of each other and, therefore, partially rest on the concrete base. However, this does not provide adequate rigidity for the enclosure. So, lateral supports are provided, as shown on View I of Drawing SK72-001, Sheet 1, Page A-2, and detailed in the upper left-hand corner of Sheet 2, Page A-4. Great care was exercised in the design of this attachment to the frame that no structural vibrations be transmitted to the enclosure and, from there, to the outside.

..There are several ways to support the upper-conical rings of the enclosure. One, shown in Drawing SK72-001, Page A-2 and in Drawing SK72-004, Page A-10, consists in supporting them by hanging from the upper level platform. In all cases, one must remember not to attach the upper enclosure rigidly to the upper bowl, since the bowl must rotate several times a day. Another way of support is by means of posts (as shown on Figure 1, Page 8), supported as shown.

(3) Quick Release of Panels

Quick-release latches must be used for securing and releasing the panels--first to save time; second because nuts and bolts would be quickly lost. A typical adjustable latch is shown, for example, as Detail I of Drawing SK72-003, Sheet 1, Page A-6. Another type is shown on the next page.

FLEXIBLE DRAW LATCH



(4) Fabrication Techniques

Fabrication techniques for building the panels described above were investigated carefully and are shown on the Drawings of Appendix A. They are only summarized briefly here, since Aerophysics is currently proposing to build the second design (octagonal shape) rather than the circular-shaped one discussed here.

Obviously, the key to success in fabricating panels as described above lies in the familiarity in forming constrained-layer materials, such as the steel-lead-steel laminate, and in insuring a perfect acoustic seal when joing panels together.

The proposed design was developed in consultation with one of the specialists in the development and forming of sound-damped materials in complex shapes:

VENEERED METALS, INC.
Post Office Box 327
Edison, New Jersey 08817

There are several ways to fabricate the proposed panels. In a first way, the already-bonded sheet of steel-lead-steel is rolled into a cylindrical (or conical) shape to the proper radius. Stiffeners are then welded, or adhesively bonded in accordance with the drawings, including all properly-spaced flanges. The 60-degree segments are then sawed out of the cylinder, the thickness of the saw cut corresponding to that of the gasket. In this way, one can be sure that the eight segments will fit together, to the proper radius. In the second way, which is Veneered Metals' preferred way, each panel would be fabricated separately, the steel sheets being first formed, then bonded with the lead. Use of jigs would insure the interchangeability of all eight panels of a given ring layer.

(5) Required Modifications to Crusher Installation

In order to install the noise enclosure described above, very few modifications must be made, as far as the structure or the subsystems are concerned. Required changes are as follows:

..The deck grating, at the adjustment level, currently comes within a few inches from the crusher body, with a roughly-circular cutout. The diameter of the circle must be enlarged by one to two feet to permit passage of the enclosure through the adjustment level deck.

..The hydraulic lines (for the adjustment rams and the lock posts) must be rerouted. It is proposed to pipe them to a common area shown as View II of Drawing SK72-001, Page A-2, and detailed on the upper right-hand corner of Sheet 2 of Drawing SK72-001, Page A-4.

..To avoid having to remove panels for the near-daily greasing of the threads of the crusher, it is proposed to manifold the eight grease fittings and install an automatic greasing system (Alemite, for example). The single grease line would cross the enclosure through the same plate as the hydraulic lines. This system is inexpensive off-the-shelf hardware.

..The water lines (that cool the transmission and are used as a seal) must also be rerouted. It is proposed to do it according to View III of Drawing SK72-001, Pages A-2 and A-4. Again, care must be exercised not to allow an acoustic leak at the point where utility lines cross the enclosure.

(6) Cost of Proposed Installation

A detailed cost estimate of fabricating the proposed noise enclosure was made simultaneously with the fabrication study. Veneered Metals, Inc., submitted a proposal to Aerophysics to fabricate all panels fpr the enclosure of Appendix A in accordance with the Aerophysics drawings for a fixed price of $19,000.00. On the other hand, we estimated the cost of materials and shop labor for a production run of, say, more than 20 units, to less than $5000. On that basis, one would guess a cost of producing and installing of about $25,000, which is less than ten percent (10%) of the cost of the crusher without the motor.

(7) Merits of the Proposed Design

There is no doubt in our minds that the design will work acoustically. The calculated noise outside the enclosure is estimated around 75 dB(A). Since one designs for an OSHA requirement of 85 dB(A), there is an ample safety margin, to allow for possible "leakage", if the enclosure is not perfectly tight. For the first time, we believe it safer to be conservative. Should the enclosure turn out to be overdesigned, it would be easy to reduce the gauge of the material. One cannot reduce the gauge of the outer "skin" (16 gauge) because this is the minimum acceptable sturdiness. But one could use one- (1) pound lead instead of two- (2) pound lead. The major advantage is that the maximum weight of the heaviest panel would be reduced from 75 pounds to 65 pounds, which is easier to handle for an attendant alone.

Is the design practical?

..Accessibility: The hydraulic rams can be reached and operated by removing two panels strategically located opposite each one of them which takes only a few minutes. The panels can be "peeled off" as required, for example, to trace an oil leak. In total, the time required to remove panels and replace them in the routine maintenance chores is negligible.

..Ruggedness: The criticism may be made that the panels will be subject to abuse, be bent out of shape, and therefore, will not fall back into place when reassembled. Everything is relative and, obviously, the panels can be damaged in the crusher environment, and in our second design, we looked for a more sturdy solution. However, we do not believe that an installed panel can be damaged by a rock slide. If the 16-gauge outer "skin" were to prove not rugged enough, the sandwich material can be fabricated using a 16-gauge corrugated "skin". In the case where some panels would be bent out of shape where disassembled, one could have some spare panels available, since there are only four types of panels for the whole unit.

..Safety: First, the proposed sandwich panel presents no fire hazard.

Second, it has been claimed that any sound enclosure presents a safety hazard, because when trouble arises, the operator can hear it by noise changes ahead of time. This is true, but the situation remains the same with a noise enclosure. After a while, the operator will become accustomed to the new lower operating noise of the crusher and will detect, as before, a change in noise level that can spell trouble and require preventive action.

The Aerophysics design was reviewed by Jackson County Iron Company on 2 March 1977, and a valid objection concerning safety was raised. It was stated that, for safe operation, the operator located at the hydraulic ram, placed in the southeast corner of the adjustment platform, must be able to see the ram when the bowl is being advanced one notch. To remove all panels to make this possible is unpractical.

..Conclusion: The design discussed here was the "first pass" at the problem. It would work, but potential operators found it too complicated and too fragile, to which we agree. For Jackson County this design is not recommended. There are situations, in which we can see that it would be very desirable, and this is why we took the trouble to document it rather fully.

Discussion of the Second Proposed Noise Control Design (Octagonal Shape)

(1) General

The second design was an attempt at making up for the shortcomings of the first design, which were discussed in the previous section. The basic thinking is the same, i. e. a "tight skin" enclosure, but, to be practical, it is a little less tight! To simplify fabrication, the second design uses straight instead of curved panels. However, One finds quickly that the enclosure then becomes too heavy to be dismantled by hand. But, if one talks to the Jackson County people, they tell you that there is nothing wrong about picking up the enclosure panels with the overhead crane. Also, with straight panels, large doors become feasible, and provide unrestricted access to the hydraulic rams. Four 8-ft wide doors are therefore positioned, at the adjustment level, in front of the hydraulic rams. In addition, for the semi-fixed panels between the doors, there is crawl space for the operator to reach any point of the crusher. Finally, on the drive level, four small triangular doors allow access to any part of the lower surface of the crusher. Obviously, the two lower noise enclosures, protecting respectively the crusher lower access door and the countershaft, are the same for the second design as for the first one.

(2) Genesis of the Second Design

The second design originated in reaction to the lack of enthusiasm displayed by personnel of the Jackson County Iron Mining Company when they were shown the first design, on 2 March 1977. The issue of safety was raised and would have forced a redesign by itself. However, the following suggestions by Jackson County personnel were worth listening to:

- straight panels were prefereable to curved panels
- because of the availability at Jackson County of an overhead crane, panels did not have necessarily to be light enough to be carried by one man. This leads to a self-standing structure.
- for daily inspection and maintenance, access through hinged doors would be preferable to panel removal
- with the doors open, it would be desirable to have a crawl space between the enclosure and the crusher
- it would be nice to be able to use the same enclosure for secondary and for tertiary crushers, for full interchangeability.

Rather than go back home and work on a new design incorporating the above suggestions, Aerophysics personnel, Messrs Foshag and Munchberg went to a local building supply store, bought lumber and tools and experimented with alternate concepts on the south-side tertiary crusher. Results of an early experimentation are shown in figure 9. It showed that the crusher, at the adjustment level, could be complete-

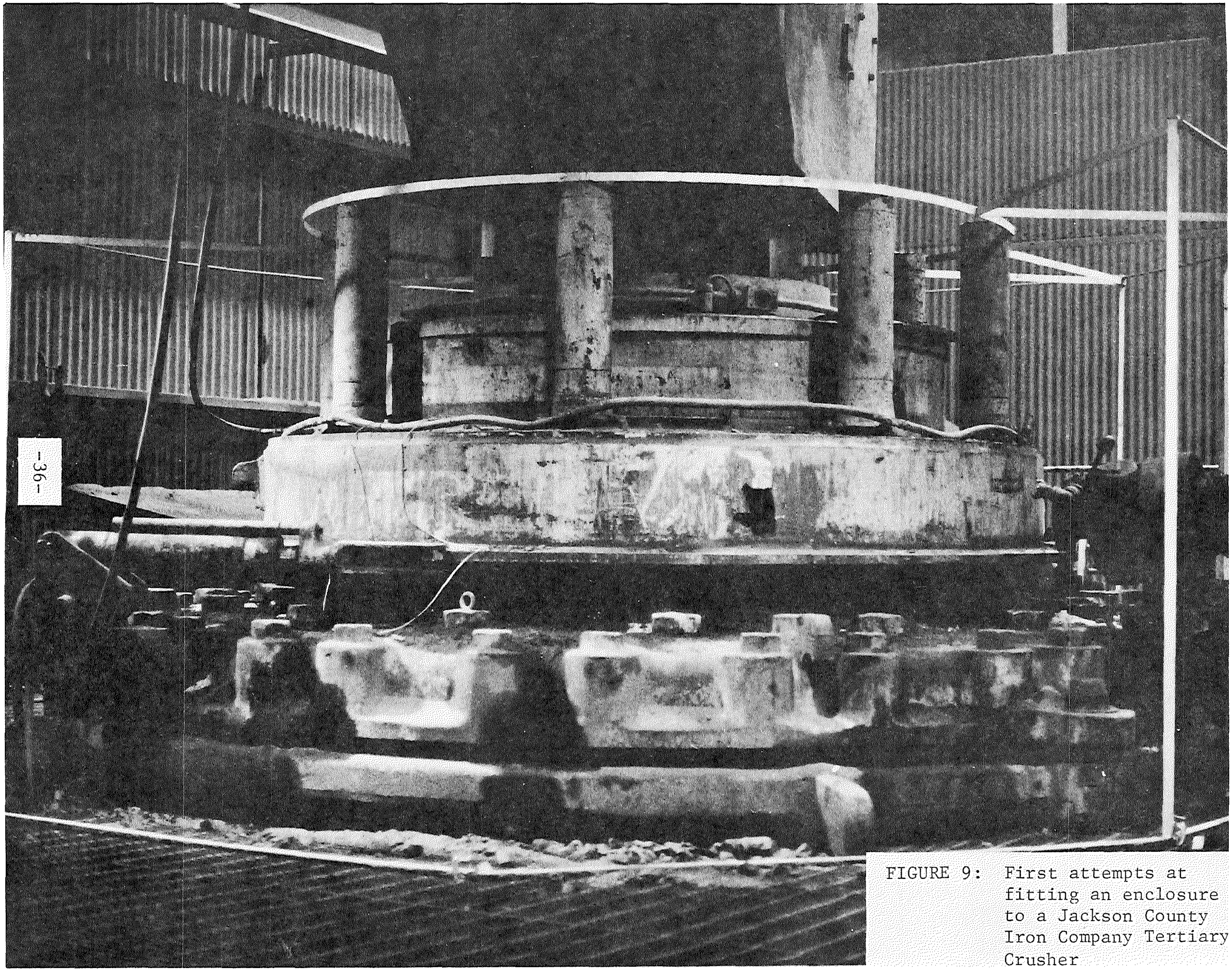


FIGURE 9: First attempts at fitting an enclosure to a Jackson County Iron Company Tertiary Crusher

ly enclosed, using an octagonal structure, made of standard 4-by-8 panels. The nearly-completed structure at the adjustment level is shown on figure 10. The octagon shape is made to transition to the square shape of the crusher concrete base by a series of triangular panels, as shown on figure 11. This approach met with the approval of the Jackson County personnel, and therefore a second design was developed on that basis. Preliminary drawings for the second design are the thirteen (13) sheets shown in Appendix B of the report. These drawings are discussed in some detail in the next paragraph.

After the drawings were completed, a 1/10-scale mock-up of the "simplified" crusher and of the octagonal design were built. They are shown in figures 12 and 13. It will be noted that the final design is very close to the configuration tried at Jackson County Mining Company. For example, a minor change is that the upper horizontal deck has an inside cut-out which is square, rather than circular, to facilitate the connection, by a flexible boot, of that deck with the square (or rectangular) chute above. Also, note that the door panels are left out on the mock-up and that the semi-permanent panels are left out of most of the mock-up for clarity. In fact, all flat sides are to be covered with the noise-insulating composite sheet described earlier.

(3) Details of the Drawings

An isometric view of the crusher enclosure is shown on Drawing SK 72-100, page B-2, which shows clearly the self-standing structure which supports the lead sandwich panels which form the enclosure. The view also clearly shows the flexible skirt adapter which continues the enclosure up to the rock chute above, and is not shown in the mock-up pictures. Note that the upper decking includes, in addition to the noise barrier sheet, a plywood sheet, on which the crusher operator can stand. If the crusher gets jammed, the operator has easy access to the bowl by standing on that platform and unzipping the skirt adapter. This is a feature that does not currently exist, since there is a semi-portable platform only on one side of the crusher.

In an early version of the octagonal enclosure, the enclosure was to be partially supported by the crusher body and the feed platform. In the version shown here, the crusher hooks are only used for stabilizing the framework, as shown on Drawing SK 72-106, page B-14.

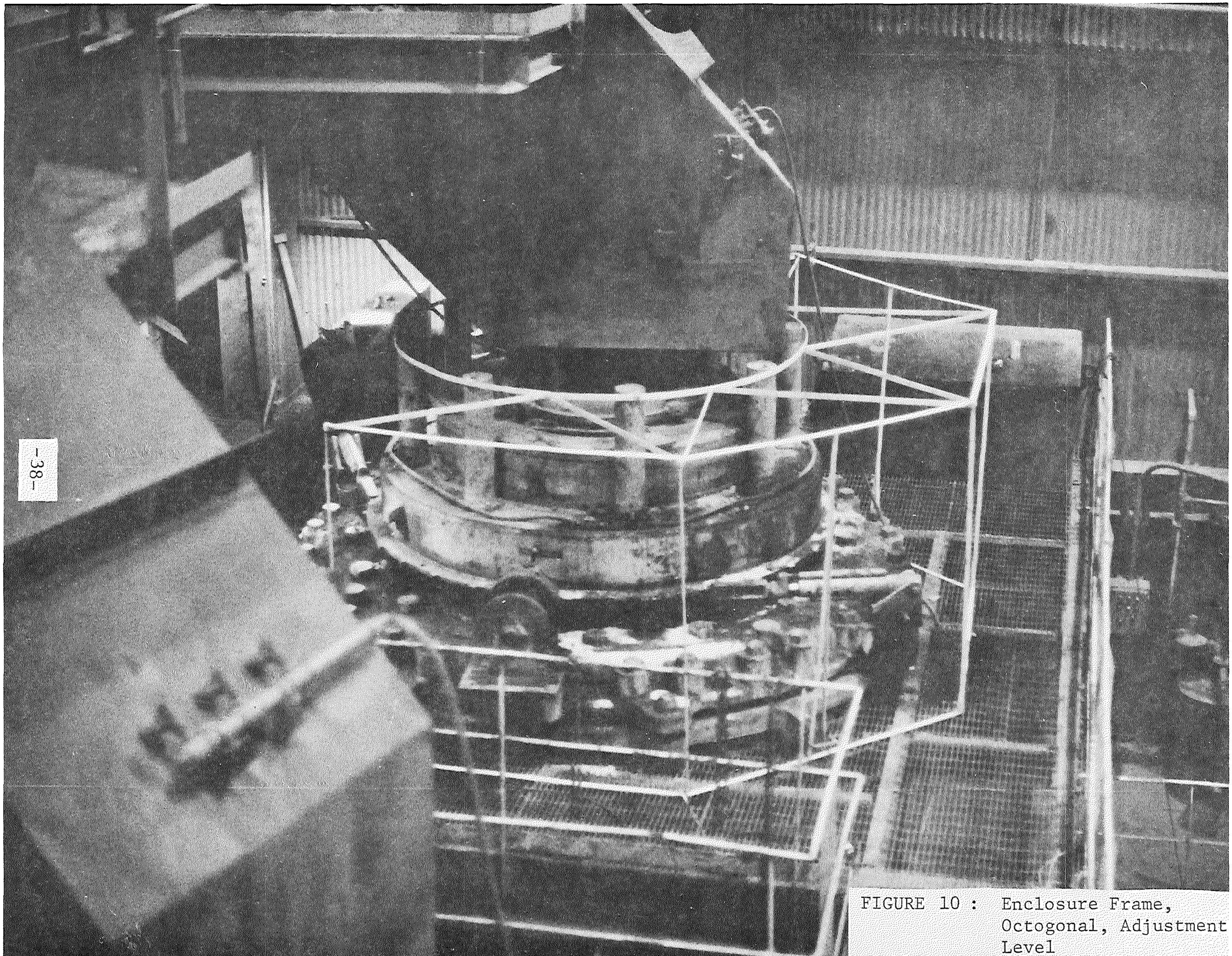


FIGURE 10 : Enclosure Frame, Octogonal, Adjustment Level

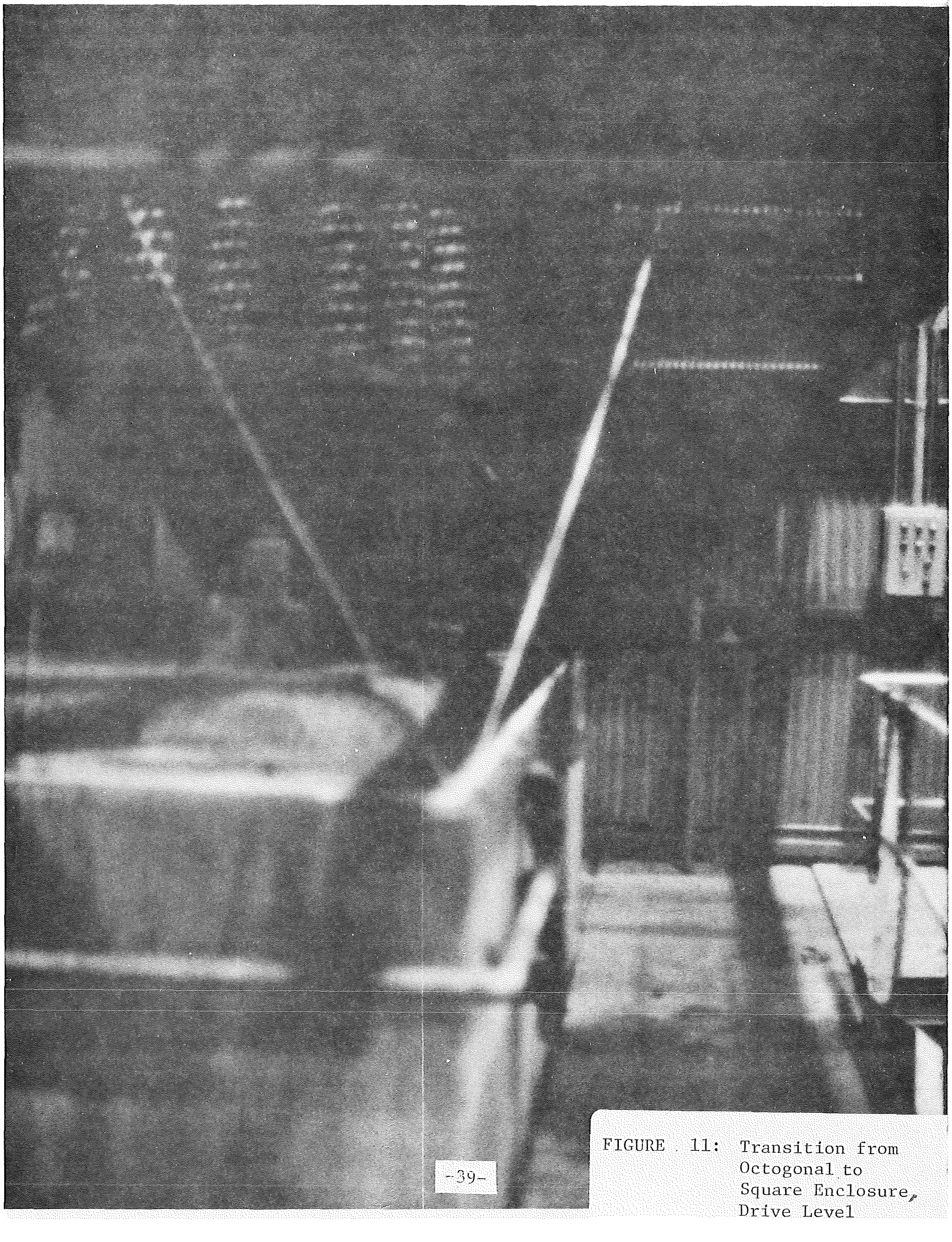


FIGURE 11: Transition from Octogonal to Square Enclosure, Drive Level

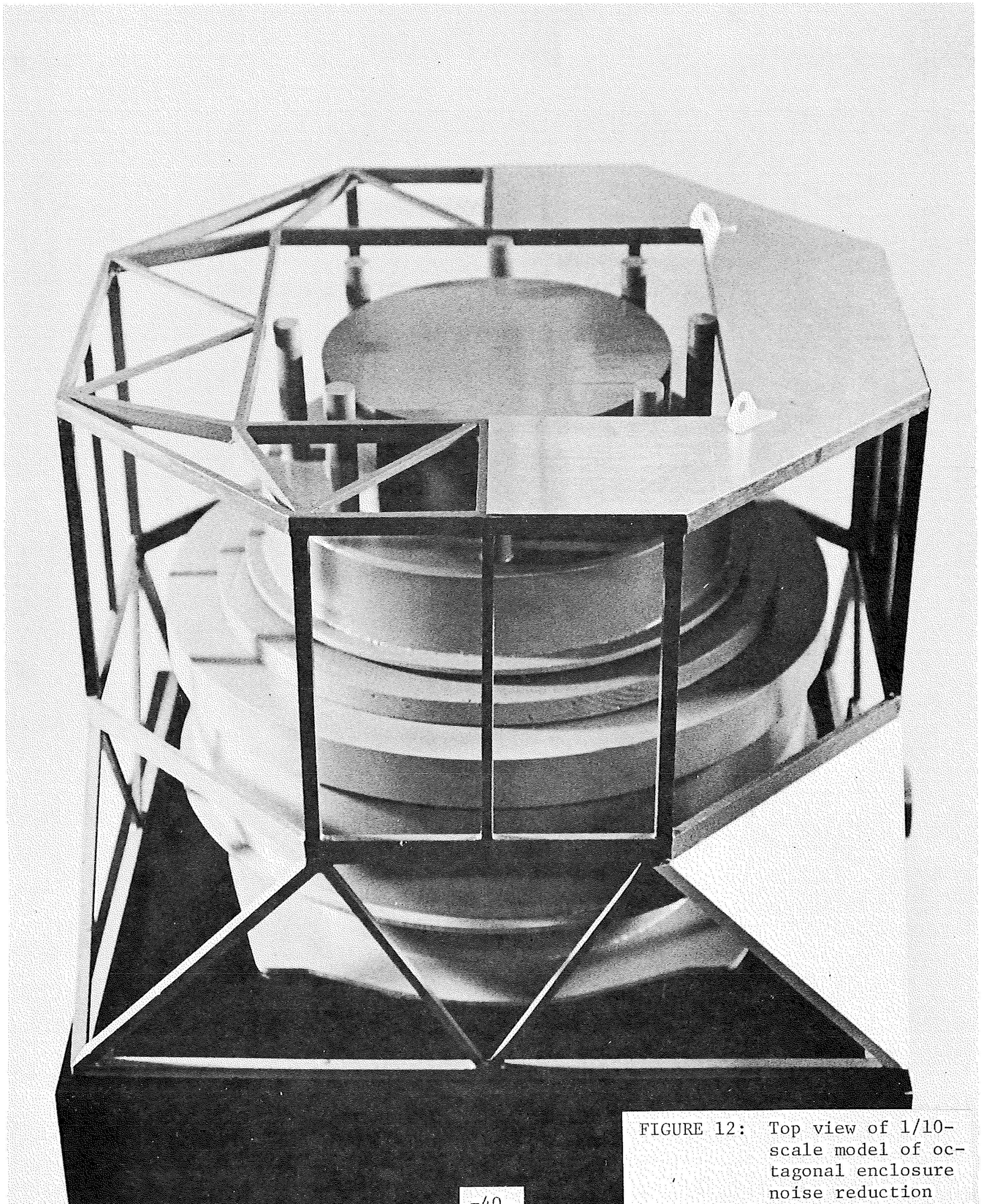


FIGURE 12: Top view of 1/10-scale model of octagonal enclosure noise reduction concept

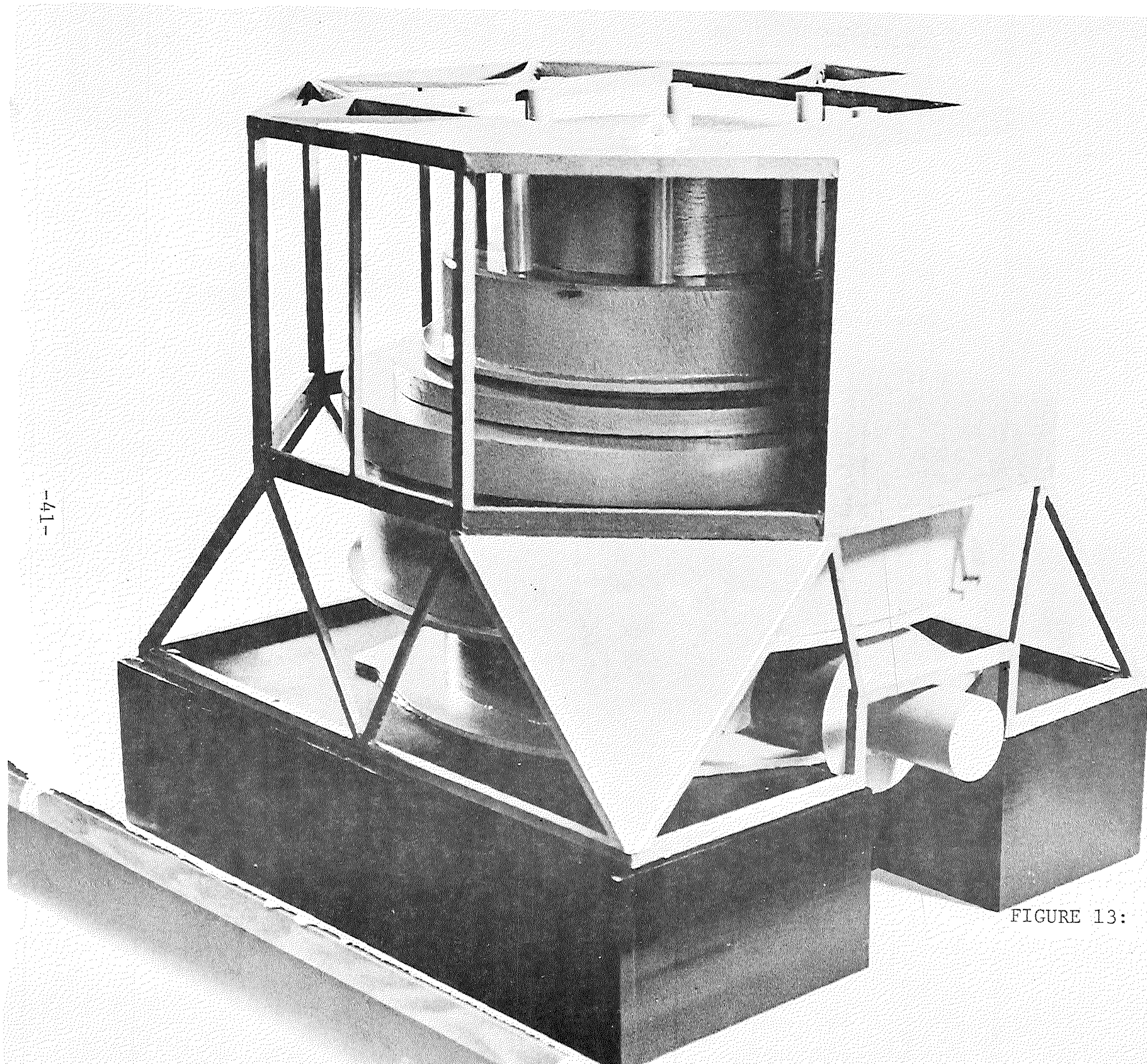


FIGURE 13: Side view of 1/10-scale model of octagonal enclosure noise reduction concept (doors and skin mostly removed)

Each of the framework sub-assemblies are called out on Drawing Sk 72-100 and detailed in the following pages, through the four additional sheets of Drawing SK 72-100 and two sheets of Drawing Sk 72-101. All other drawings are self-explanatory.

As far as the removal of the enclosure, partial or total, is concerned, a number of options are available. The enclosure consists of essentially two levels, the drive level and the adjustment level. It is proposed that the drive level half-enclosure be semi-permanent, and a horizontal split be provided with the adjustment level half-enclosure. The latter one could be hoisted in one piece, using four lugs on the upper deck and the overhead crane. In the case of the Jackson County plant, the whole enclosure could be hoisted away in one piece and stored at the other end of the plant very easily.

In another version, the horizontal upper plywood deck is removable in two pieces, so that the crusher mantle can be removed, without the need to remove the octagonal vertical walls. In all cases, the doors can be removed as required. Each weighs less than 100 pounds and can be removed by two men.

(4) Weight and cost of the enclosure

Using the drawings of Appendix B, a detailed breakdown of the enclosure panel areas and weights was prepared. The following was found:

Area of shield:	766 ft^2
Weight of shield: 766 x 5.25 =	4020 lbs
Weight of structural elements:	1465 lbs
Weight of seals, hardware & misc.:	835 lbs
Total weight:	6,320 lbs

The fabricated cost of the shield material is estimated to be \$2.80 per square foot. Several suppliers are available and delivery in 4-by-8 ft sheets is approximately 3 weeks after receipt of order. The cost of steel is assumed to be 32 cents per pound.

The cost breakdown of materials is as follows:

Sound Shield Material:	\$ 2,145
Structural members:	469
Hardware, seals and fittings:	2,450
Total:	\$ 5,064

At this time, we estimate a sale price of the crusher enclosure of \$ 15,000.

(5) Merits of the Proposed Design

The proposed octagonal sound enclosure was designed to answer criticism of the first design by Jackson County Mining Company personnel and seems to us to meet very well the Jackson County plant requirements.

It is simple, and uses structural steel elements and flat panels in a straight-forward manner. It is therefore cheap in relationship to the cost of the crusher with which it is installed. It requires practically no modifications to the Jackson County crusher installation, except to the adjustment level grating.

It is relatively versatile: the same unit can be used interchangeably for the secondary and the tertiary crusher at the Jackson County plant. We can think immediately of about 75 crushers in the Mesabi range area that could use the design with only minor changes on a retrofit basis.

It is rugged. Now that weight is not an important consideration anymore, should it be found in usage that 16 gauge cold roll steel does not stand up to the duty, one could use 14 gauge CRS instead, even on the doors.

The design is safe: no fire hazard, nor delays in access to the crusher in case of emergency.

When it is all said and done, the only way to ascertain the merits of this design against other designs is by building it and putting it in service for one year. We feel that this design is original enough and promising enough to deserve to be built, even if other design concepts appear equally attractive now. It is a low-risk concept that should offer no surprises.

CONCLUSIONS AND RECOMMENDATIONS

1. Two designs for the noise control of secondary and tertiary crushers were developed. Both will satisfy the noise control requirements. The second design is better adapted to the situation at the Jackson County Iron Company taconite plant than the first one. It is recommended that a prototype of the second concept be installed at the Jackson County plant at the earliest possible date, either on the secondary or on one of the tertiary crushers.

2. One may argue long about the merits of the proposed Aerophysics designs, their life, etc. The only way to assess performance and cost of noise control devices is by building and testing them over a long period of time. A multiple approach to designs is warranted here because of the relatively modest cost involved.

3. Having said that it was too early to conclude about the practicality of noise control enclosures for taconite plant crushers, it is not inconsistent to add that noise control of crushers, as proposed herein, appears promising and economically viable.

REFERENCES

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2 Phillips, W. G., and Prahl, F. A. III, Taconite Secondary Crusher Noise Source Diagnostic Study, Bolt, Beranek and Newman, Inc., Report No. 3545, May, 1977.

3 Prothero, K. L., Case Histories in Noise Control, a paper presented at 1976 May Safety Conference, Lake Superior Mines Safety Counsel, May 13, 1976.

4 Instruction Manual for Standard and Short Head Models, Symons Cone Crusher, Manual No. M514, published by Rexnord Process Machinery Division, Post Office Box 383, Milwaukee, Wisconsin 58201.

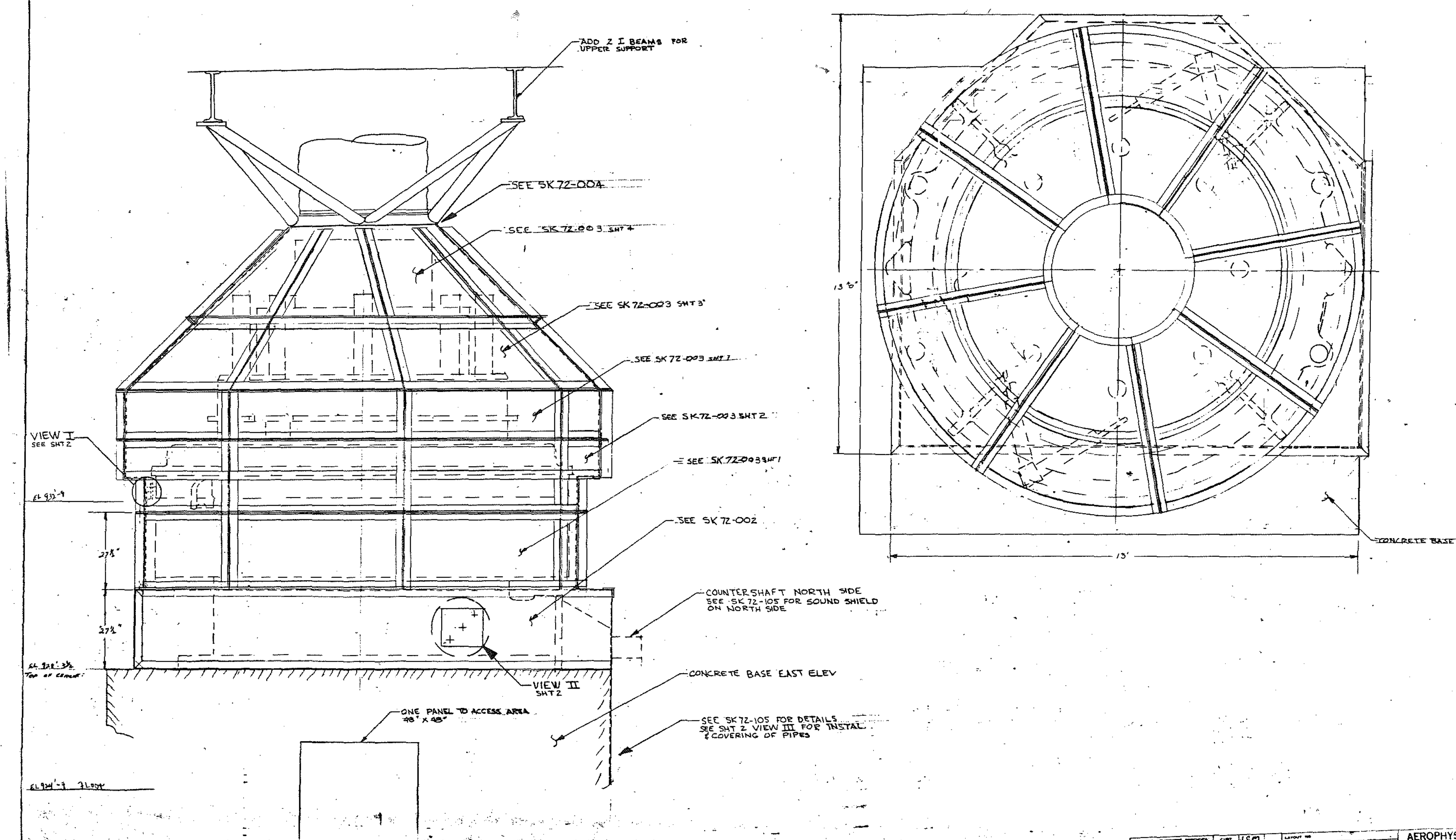
APPENDIX A

PRELIMINARY DRAWINGS

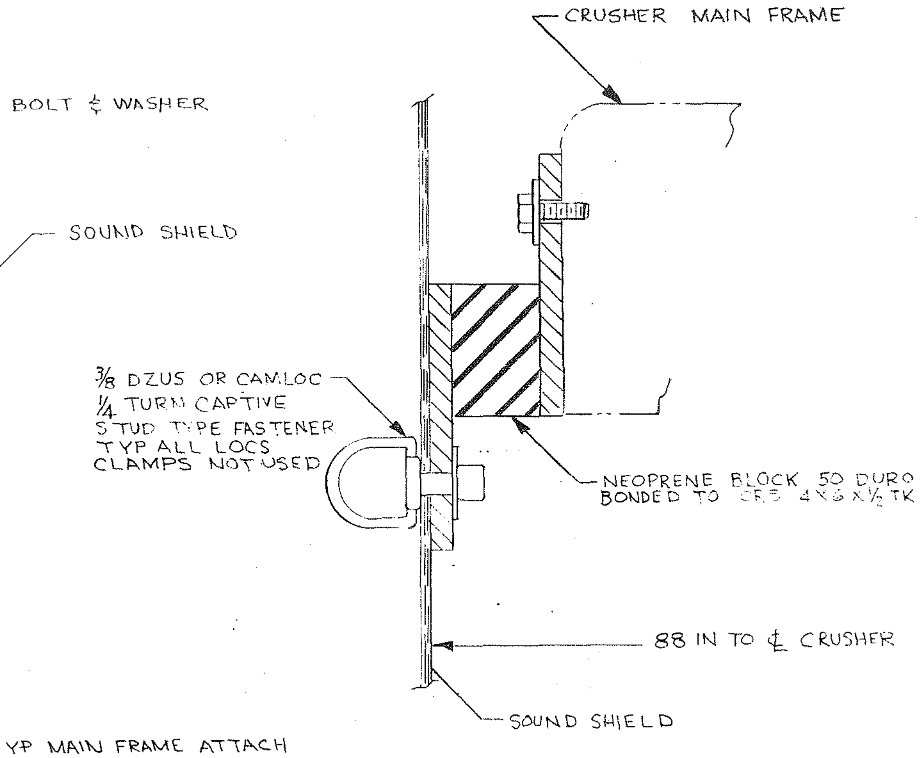
First Design for a Noise Enclosure: Symons 7-Foot Standard Heavy-Duty Crusher

LIST OF DRAWINGS

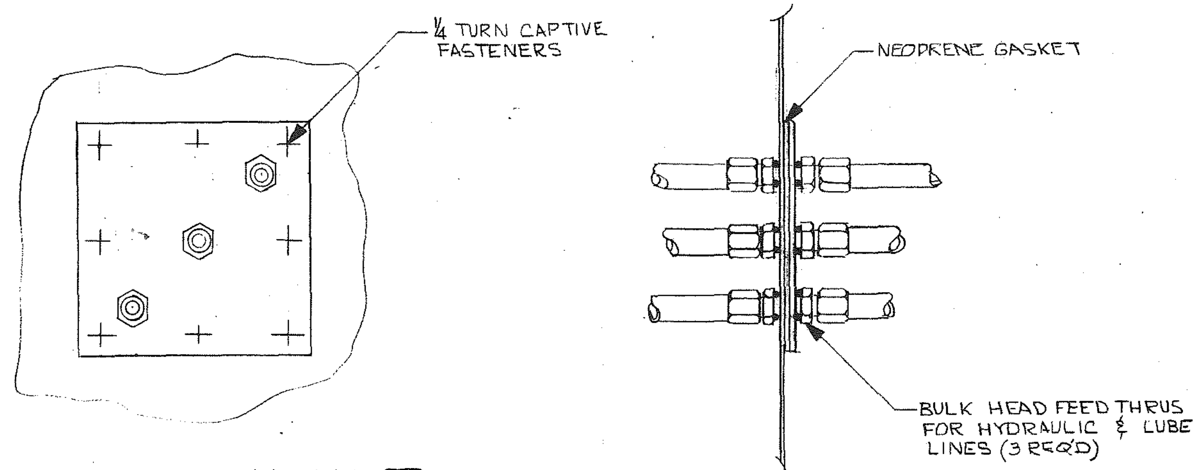
RECTANGULAR BASE 11FT X 13 FT X 27IN FABRICATED FROM 4'X8' SHTS. TO BE A SEMI-PERMANENT INSTALLATION
ROLLED CYLINDRICAL & CONE SECTIONS TO BE FORMED IN SEGMENTS THEN ASSEMBLED IN JIGS
ALL METAL PARTS TO BE SPOT WELDED TO 16GA SHEET
RUBBER TO METAL BONDS TO BE MADE WITH 2 PART TYPE EPOXY
TWO HANDLES PER PANEL FOR HANDLING
INSTALL AUTOMATIC LUBRICATION SYSTEM (ALEMITE)
SOUND SHIELD MATERIAL - 16GA. CRS OUTSIDE .031 LEAD & 26GA. CRS INSIDE
MAX DIA 14'4"



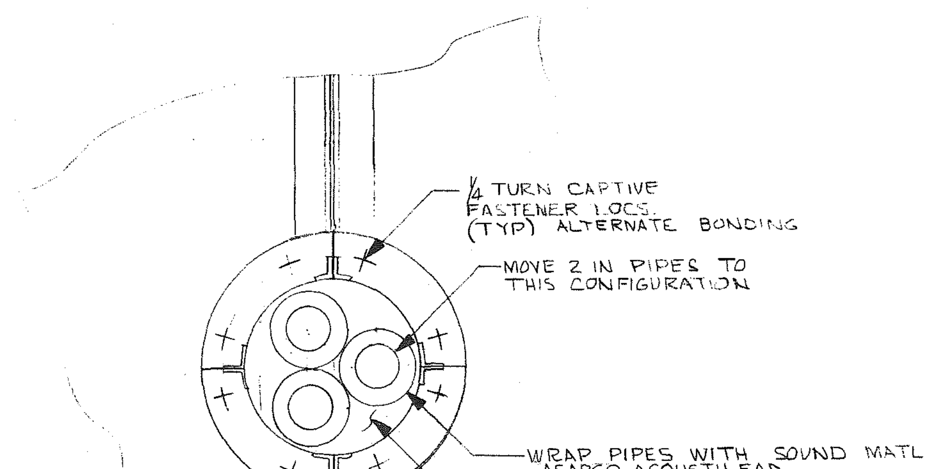
CUST J.C.M. / PROJECT #72	DRAWING TITLE: PRELIMINARY SOUND SHIELD ROCK CRUSHER	AEROPHYSICS COMPANY WASHINGTON, D.C. 20006
	SCALE 1 IN. = 1 FT.	SK 72-001
		SHEET 1 OF 2

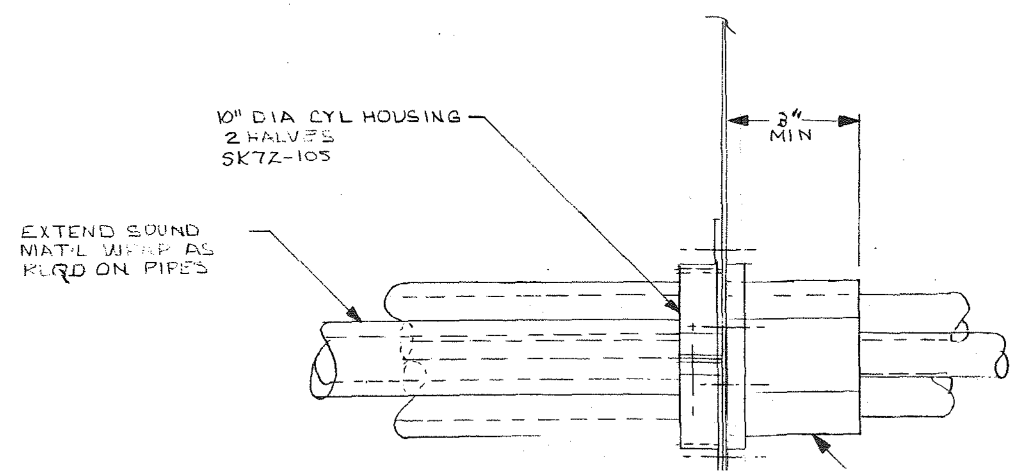


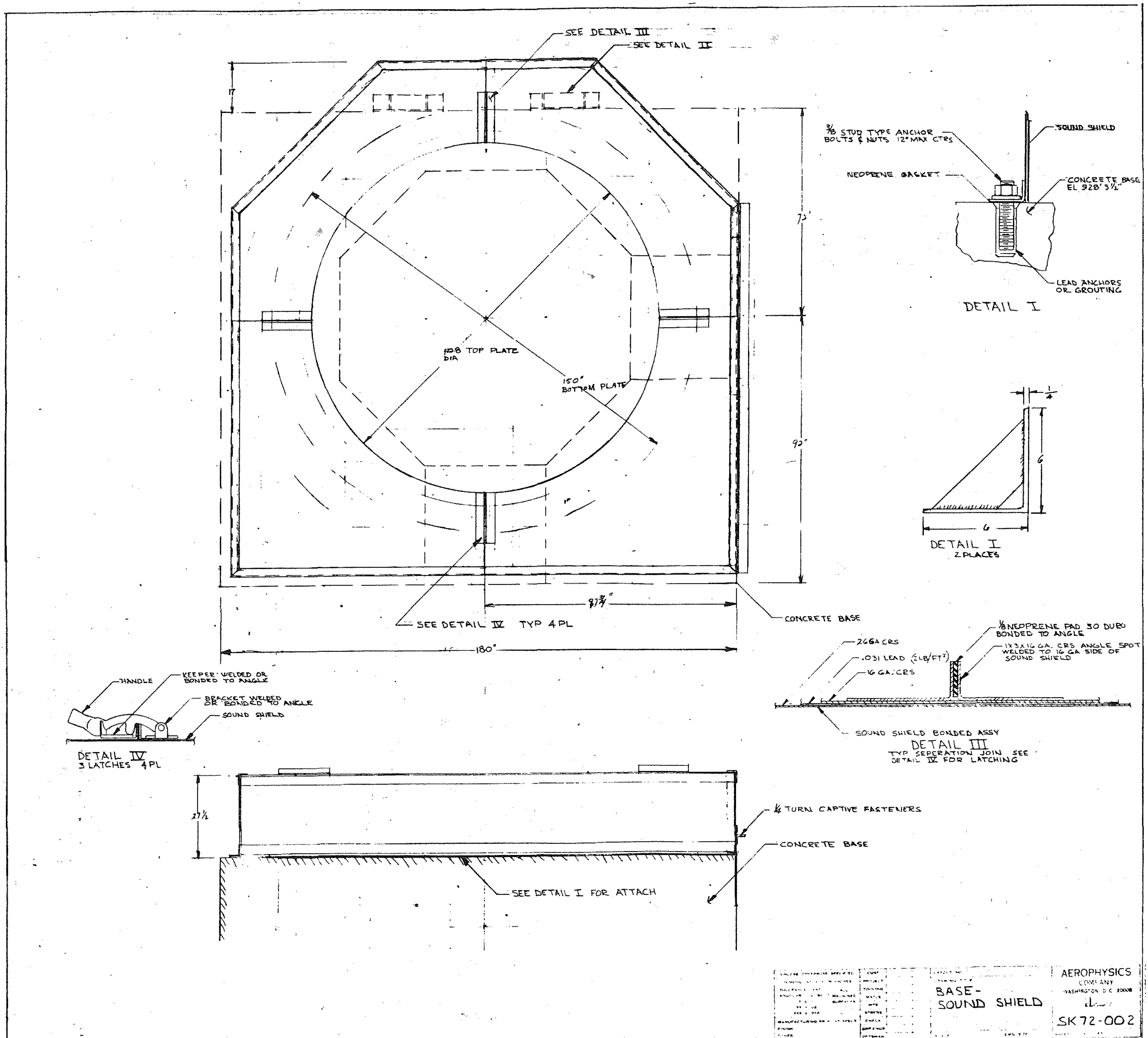
VIEW I SEE SHT 1



VIEW II SEE SHT 1

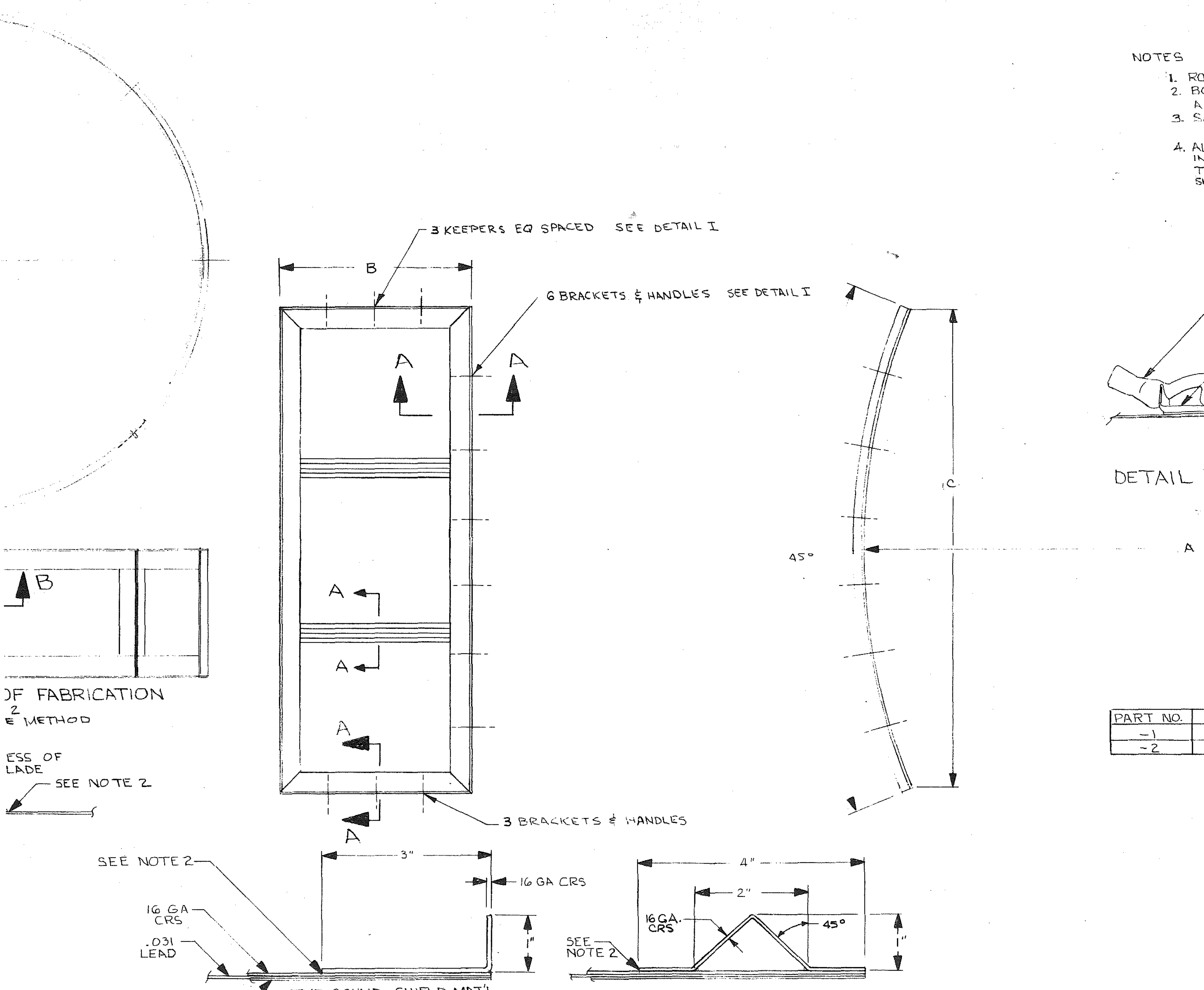


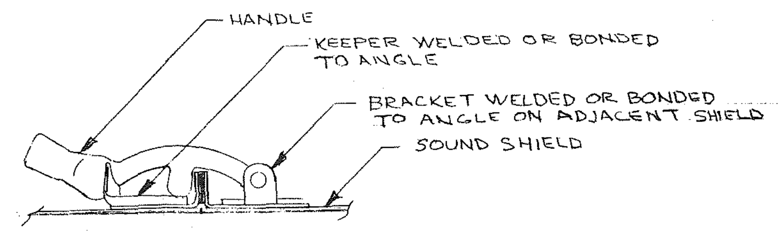



SEE DETAIL III
SEE DETAIL II
17
3/8 STUD TYPE ANCHOR BOLTS & NUTS 12" MAX CTRS
SOUND SHIELD
NEOPRENE GASKET
CONCRETE BASE EL 928' 3 1/2"
LEAD ANCHORS OR GROUTING
DETAIL I
108 TOP PLATE DIA
150" BOTTOM PLATE
73"
92"
1/4
6
6
DETAIL II
2 PLACES
87 3/4"
SEE DETAIL IV TYP 4 PL
CONCRETE BASE
180"
1/8 NEOPRENE PAD 30 DURO BONDED TO ANGLE
26 GA CRS
.031 LEAD (2 LB/FT²)
1X3X16 GA. CRS ANGLE SPOT WELDED TO 16 GA SIDE OF SOUND SHIELD
16 GA. CRS
SOUND SHIELD BONDED ASSY
DETAIL III
TYP SEPERATION JOIN SEE DETAIL IV FOR LATCHING
HANDLE
KEEPER WELDED OR BONDED TO ANGLE
BRACKET WELDED OR BONDED TO ANGLE
SOUND SHIELD
DETAIL IV
3 LATCHES 4 PL
27 1/2
1/4 TURN CAPTIVE FASTENERS
CONCRETE BASE
SEE DETAIL I FOR ATTACH
BASE-
SOUND SHIELD
AEROPHYSICS
COMPANY
WASHINGTON D.C. 20008
SK 72-002

NOTES

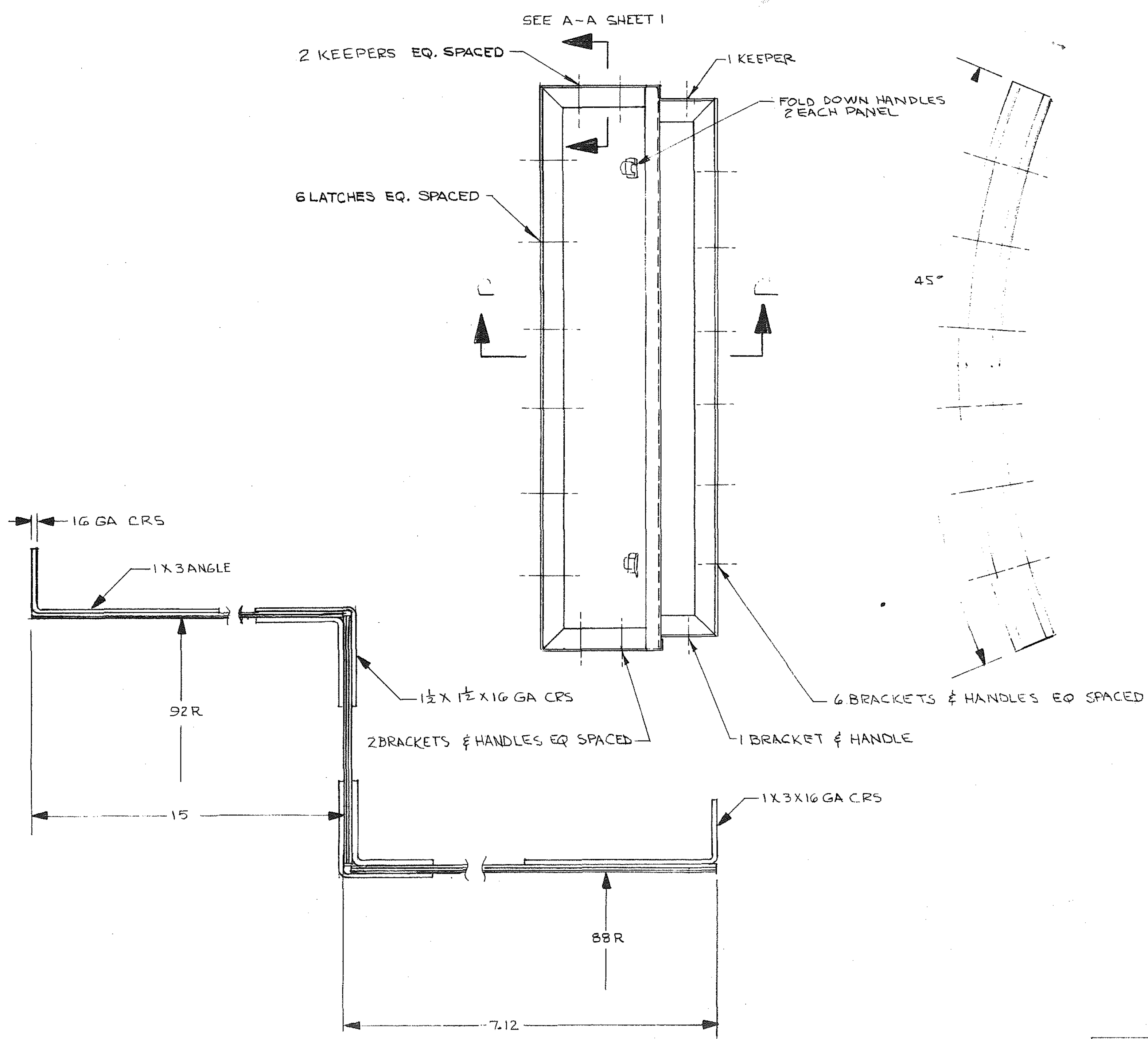
1. ROLL LAMINATED SHEET INTO CYLINDER AS SHOWN
2. BOND STIFFENERS TO SHEET PER VIEW B-B USING A CYANOACRYLATE EPOXY RESIN ADHESIVE.
3. SAW CUT INTO 45° SEGMENTS
4. ALTERNATE FAB - ROLL DIA EACH SEGMENT PLACE IN JIGS & COMPLETE FABRICATION BY WELDING THEN COMPLETE BY LAMINATING 2 LB LEAD TO 16 GA SHEET & LAMINATE 26 GA SHEET TO LEAD





DETAIL I PANEL ATTACH TYP ALL LOCATIONS

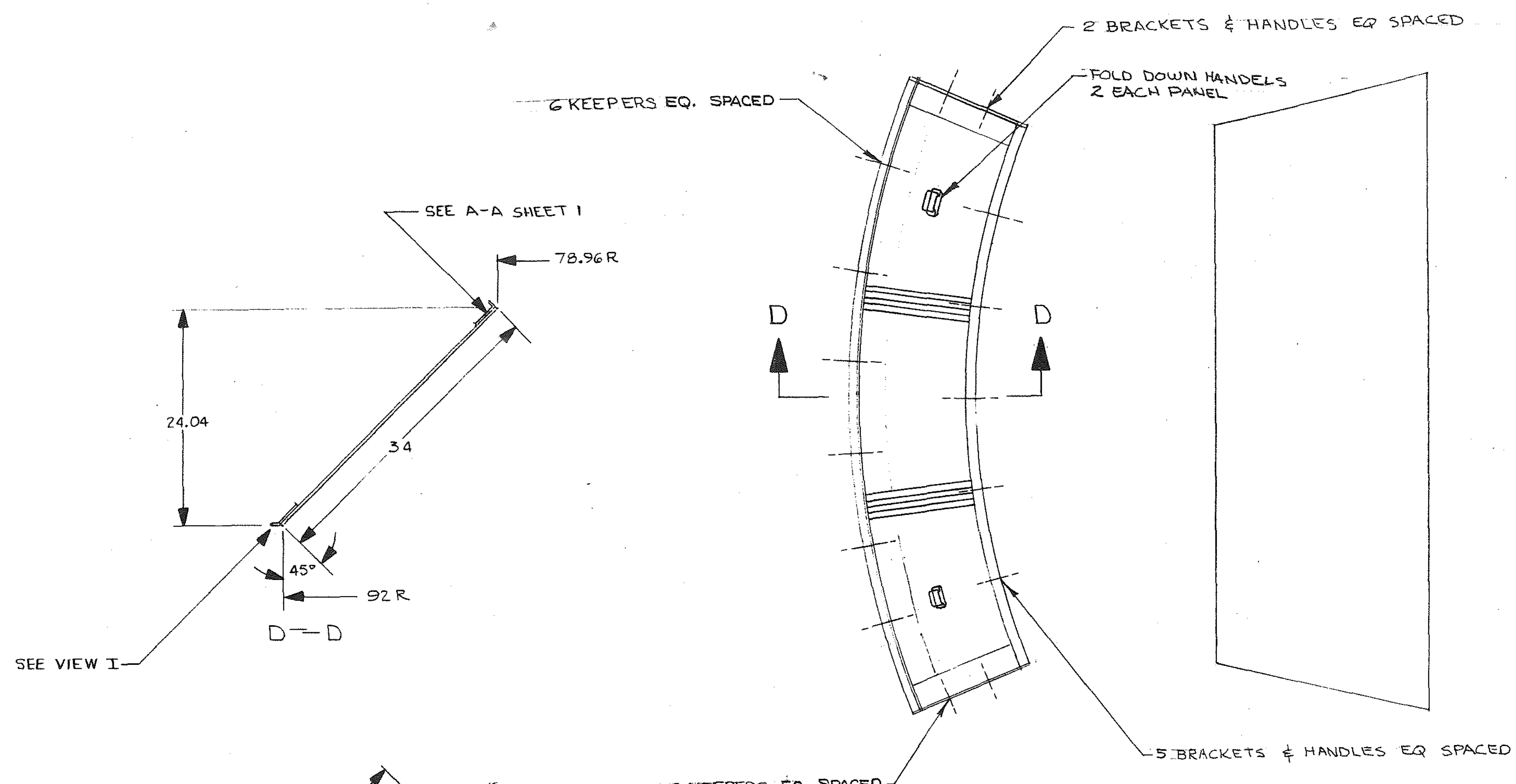
PART NO.	A	B	C
-1	78R	27.5	69.08
-2	92R	18.0	72.22

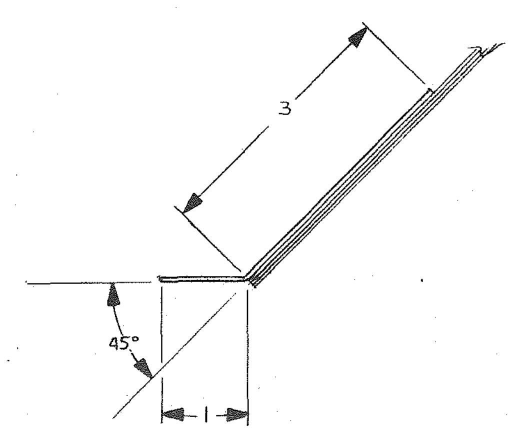


SEE NOTES SHEET 1
MAY BE MADE FROM 3 LAMINATED SHEETS
JOINED AT 1½ X 1½ ANGLES

FOR KEEPERS, BRACKETS & HANDLES SEE SHT 1

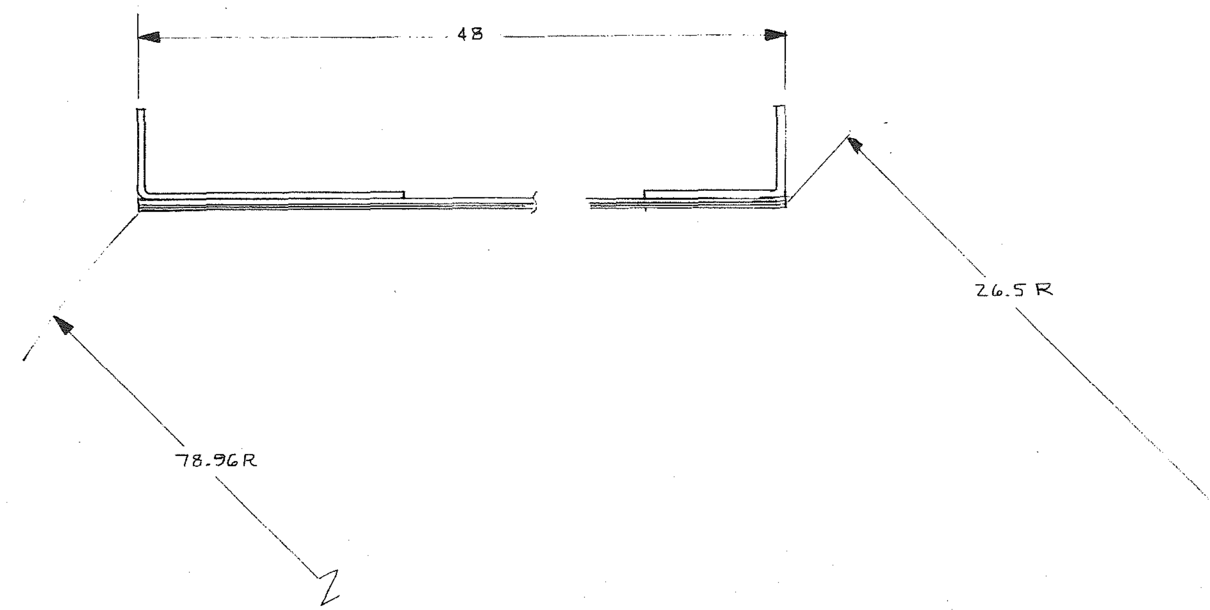
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CUST	LAYOUT NO	AEROPHYSICS COMPANY WASHINGTON, D.C. 20008
TOLERANCES ARE: ANGULAR ± 0° 30' .X ± .1 .XX ± .03 .XXX ± .010 — ALL MACHINED SURFACES √	PROJECT, TOOLING, MATLS, WTS, STRESS	DRAWING TITLE: SOUND SHIELD ROCK CRUSHER	
MANUFACTURING PROCESS SPECS	CHECK		SK 72-003
FINISH	GRP-ENGR		
OTHER	DFTSMAN	SCALE / DWG SIZE	SHEET 2 OF 4 REL



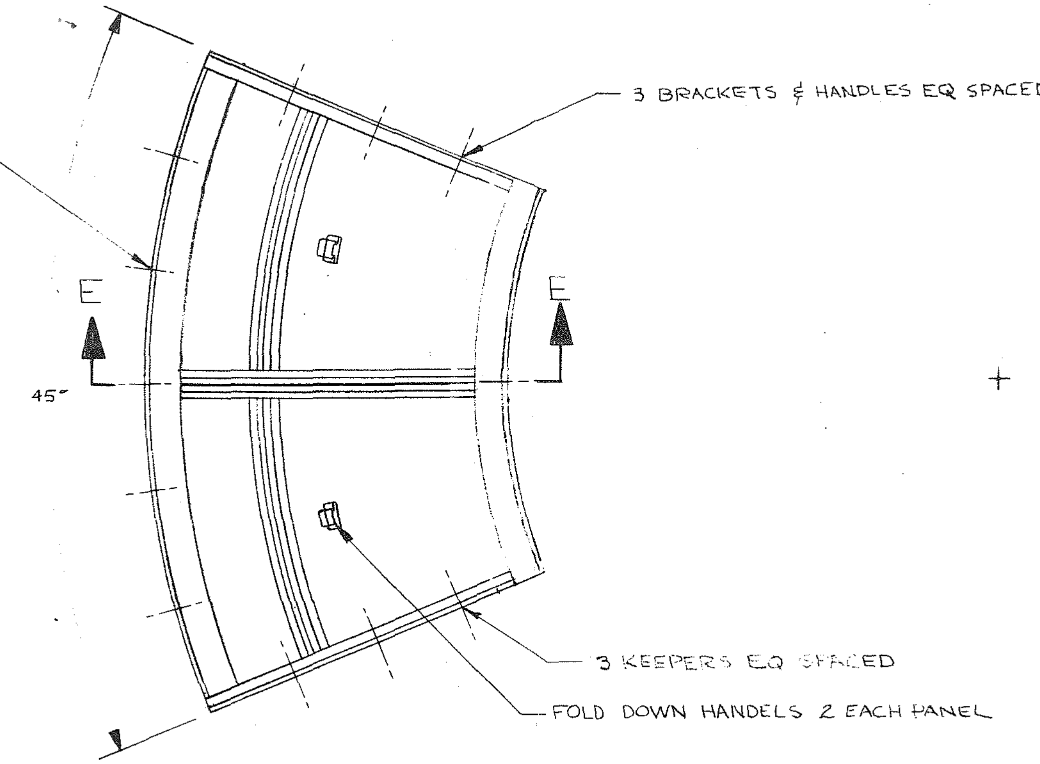


1. ROLL LAMINATED SHEET INTO CONE PER DIMS SHOWN
2. SEE NOTES SHEET 1.
3. FOR KEEPERS, BRACKETS, & HANDLES SEE SHT 1

UNLESS OTHERWISE SPECIFIED	CUST			LAYOUT NO.	AEROPHYSIC[S] COMPANY WASHINGTON, D.C.
DIMENSIONS ARE IN INCHES	PROJECT			DRAWING TITLE SOUND SHIELD ROCK CRUSHER	a
TOLERANCES ARE: ANGULAR ± 0° 30'	ALL MACHINED SURFACES √	TOOLING			SK 72-00[illegible]
		MATLS			
		WTS			
[illegible] PROCESS SPECS		CHECK			

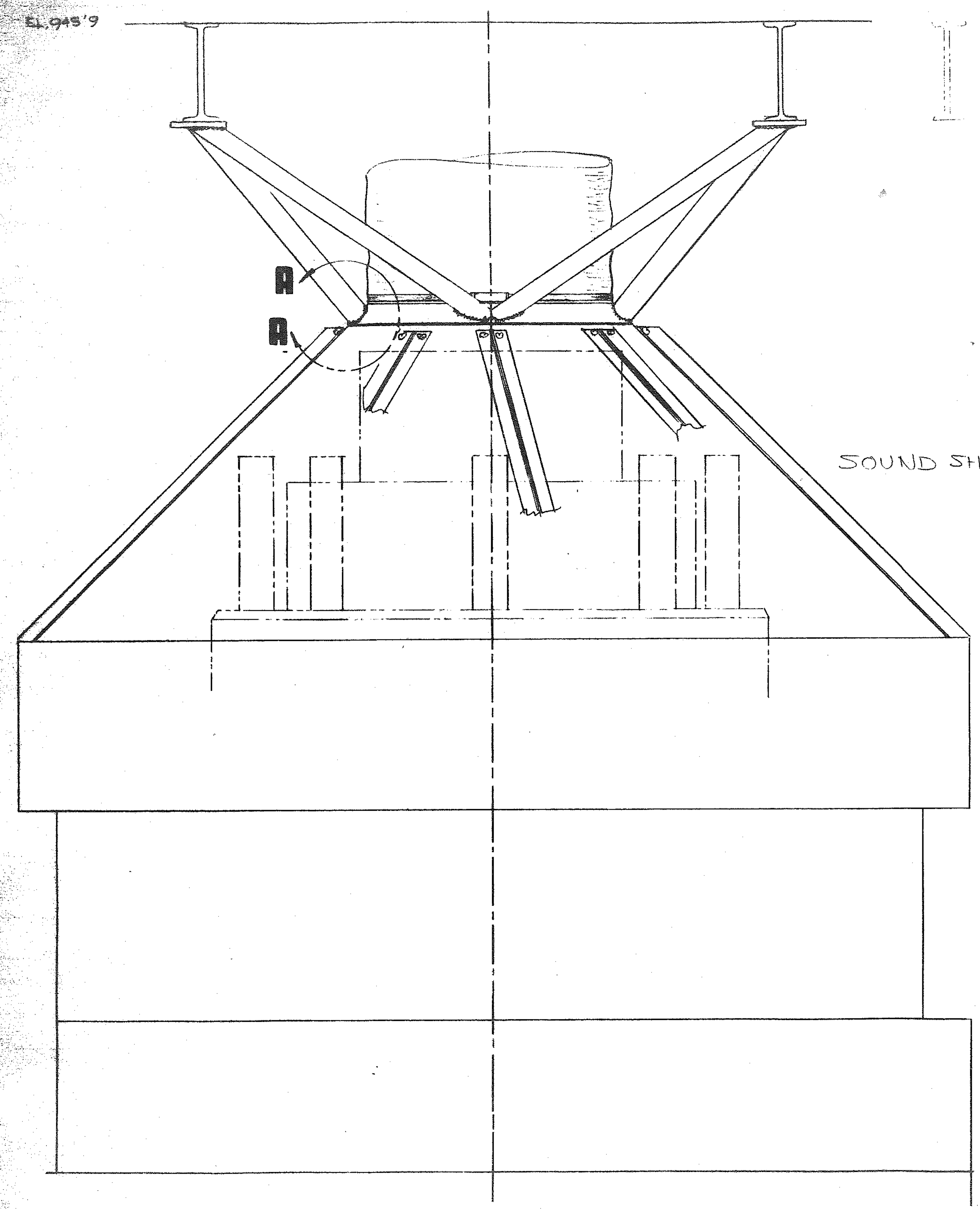


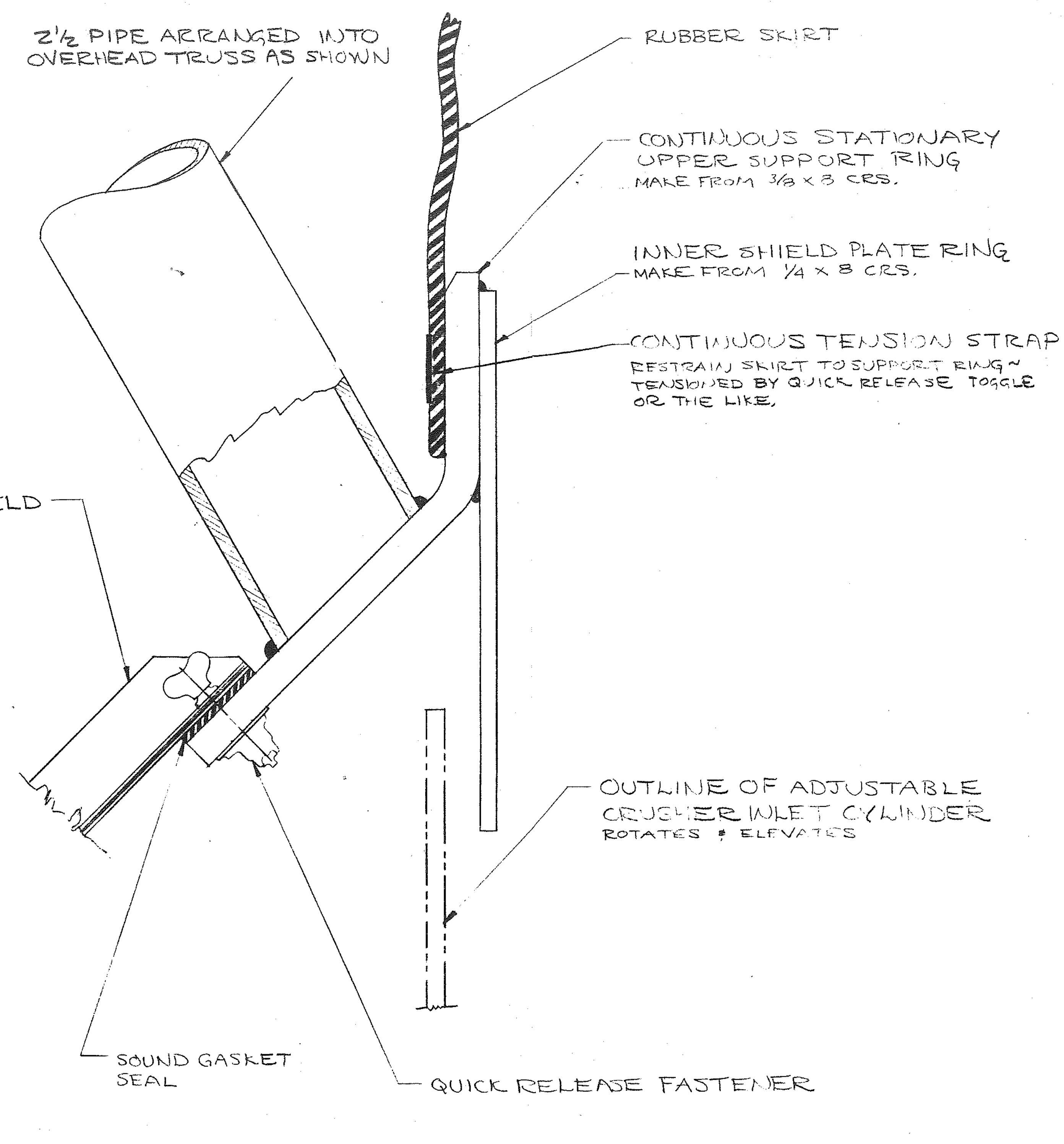
E — E



SEE NOTES SHEET 1
MAY BE MADE FROM 3 LAMINATED SHEETS
JOINED ON BOTH SIDES AS SHOWN.
FOR KEEPERS, BRACKETS & HANDLES SEE SHT 1

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CUST	LAYOUT NO.	AEROPHYSICS COMPANY WASHINGTON, D.C. 20008
TOLERANCES ARE: ANGULAR ± 0° 30' .X ± .1 .XX ± .03 .XXX ± .010 — ALL MACHINED SURFACES √	PROJECT / TOOLING / MATLS / WTS / STRESS	DRAWING TITLE: SOUND SHIELD ROCK CRUSHER	
MANUFACTURING PROCESS SPECS / FINISH / OTHER	CHECK / GRP-ENGR / DFTSMAN	SCALE / DWG. SIZE	SK72-003 / SHEET 4 OF 4 / REL





DETAIL A-A

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE: ANGULAR ± 0° 30' .X ± .1 .XX ± .03 .XXX ± .010
ALL MACHINED SURFACES √

CUST
PROJECT
TOOLING
MAT'L
WTS
STRESS
CHECK
LAYOUT NO.
DRAWING TITLE
ALTERNATE - UPPER STRUCTURE RING

AEROPHYSICS COMPANY
WASHINGTON, D.C.

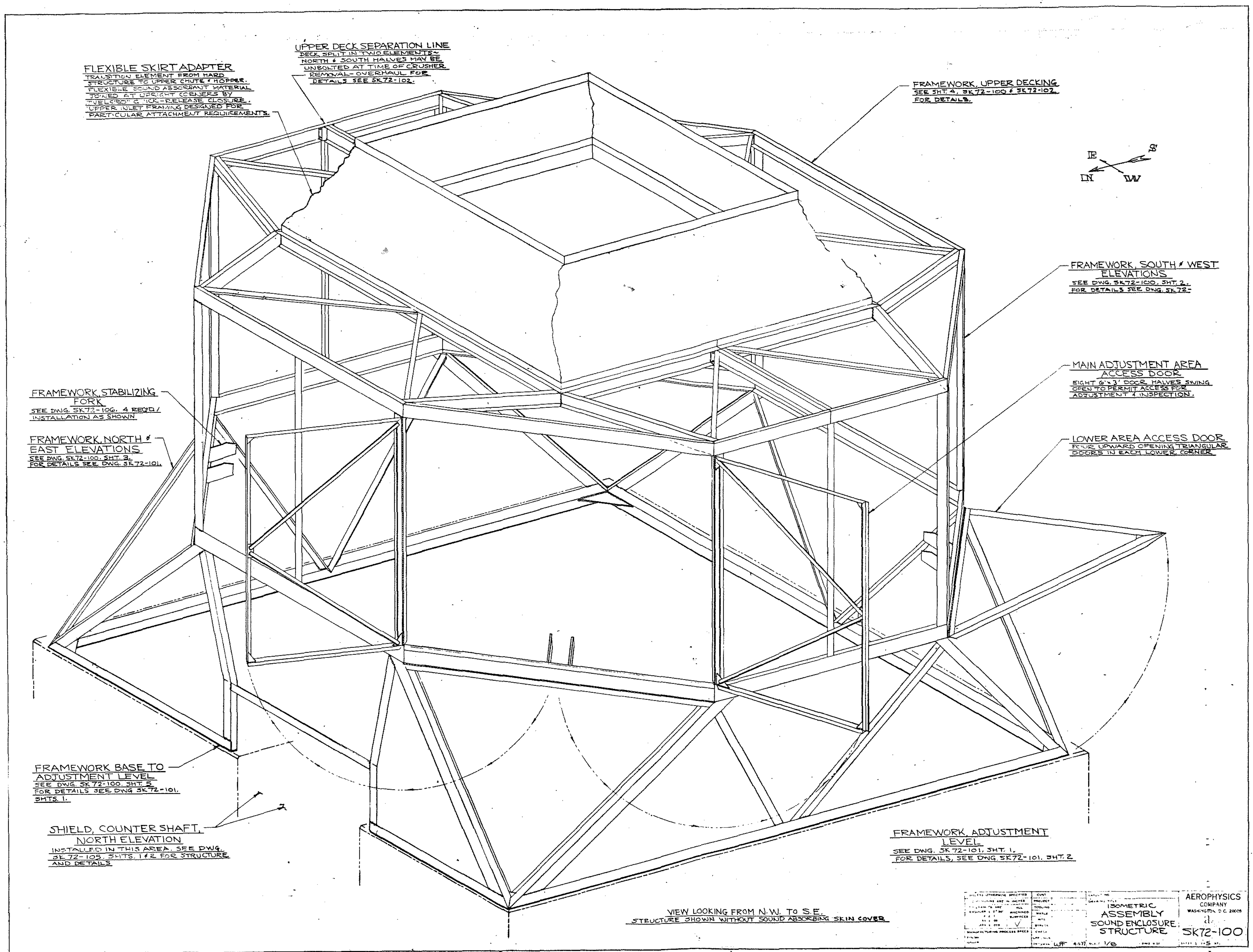
SK72-00

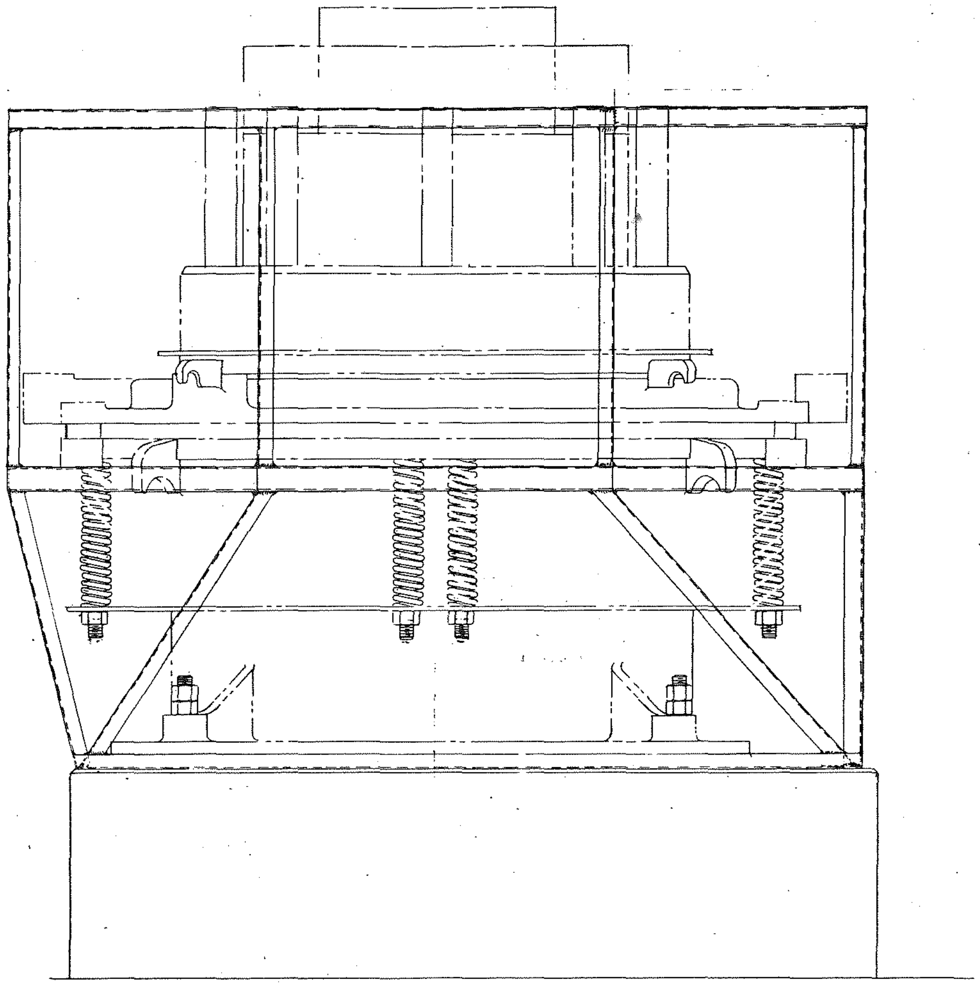
APPENDIX B

PRELIMINARY DRAWINGS

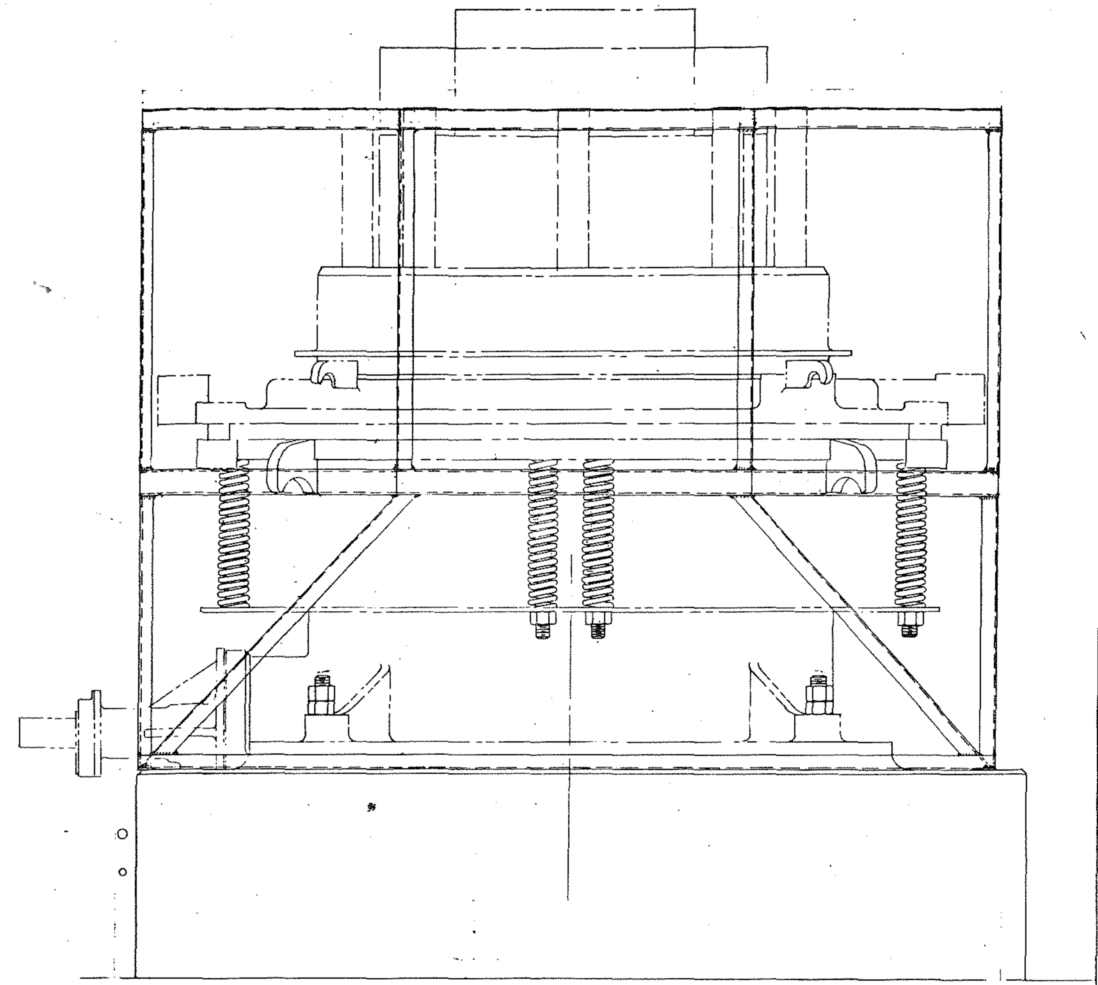
Second Design for a Noise Enclosure: Symons 7-Foot Standard Heavy-Duty Crusher

LIST OF DRAWINGS


FLEXIBLE SKIRT ADAPTER
TRANSITION ELEMENT FROM HARD STRUCTURE TO UPPER CHUTE & HOPPER. FLEXIBLE SOUND ABSORBANT MATERIAL JOINED AT UPRIGHT CORNERS BY "VELCRO" & "QC-RELEASE CLOSURE. UPPER INLET FRAMING DESIGNED FOR PARTICULAR ATTACHMENT REQUIREMENTS.
UPPER DECK SEPARATION LINE
DECK SPLIT IN TWO ELEMENTS~ NORTH & SOUTH HALVES MAY BE UNBOLTED AT TIME OF CRUSHER REMOVAL-OVERHAUL FOR DETAILS SEE SK72-102.
FRAMEWORK, UPPER DECKING
SEE SHT. 4, SK72-100 & SK72-102 FOR DETAILS.
E
S
N
W
FRAMEWORK, SOUTH & WEST ELEVATIONS
SEE DWG. SK72-100, SHT. 2. FOR DETAILS SEE DWG. SK72-
MAIN ADJUSTMENT AREA ACCESS DOOR
EIGHT 6'x3' DOOR HALVES SWING OPEN TO PERMIT ACCESS FOR ADJUSTMENT & INSPECTION.
LOWER AREA ACCESS DOOR
FOUR UPWARD OPENING TRIANGULAR DOORS IN EACH LOWER CORNER
FRAMEWORK, STABILIZING FORK
SEE DWG. SK72-106. 4 REQ'D / INSTALLATION AS SHOWN
FRAMEWORK, NORTH & EAST ELEVATIONS
SEE DWG. SK72-100. SHT. 3. FOR DETAILS SEE DWG. SK72-101.
FRAMEWORK BASE TO ADJUSTMENT LEVEL
SEE DWG. SK72-100. SHT. 5 FOR DETAILS SEE DWG SK72-101. SHTS. 1.
SHIELD, COUNTER SHAFT, NORTH ELEVATION
INSTALLED IN THIS AREA. SEE DWG. SK72-105. SHTS. 1 & 2 FOR STRUCTURE AND DETAILS
FRAMEWORK, ADJUSTMENT LEVEL
SEE DWG. SK72-101, SHT. 1, FOR DETAILS, SEE DWG. SK72-101, SHT. 2
VIEW LOOKING FROM N.W. TO S.E.
STRUCTURE SHOWN WITHOUT SOUND ABSORBING SKIN COVER
ISOMETRIC ASSEMBLY SOUND ENCLOSURE STRUCTURE
AEROPHYSICS COMPANY
WASHINGTON, D.C. 20009
SK72-100
SCALE 1/8



SOUTH ELEVATION



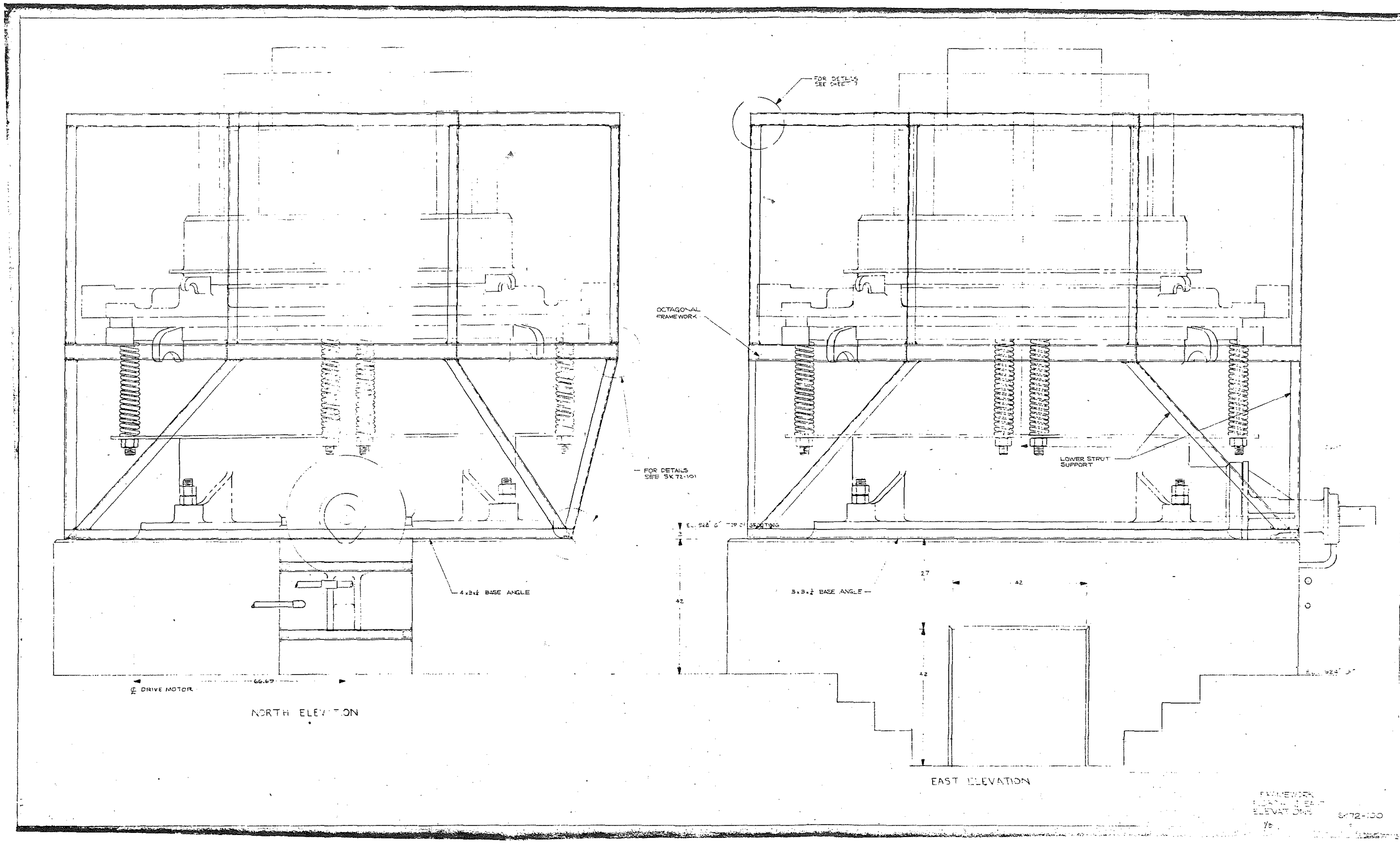
WEST ELEVATION

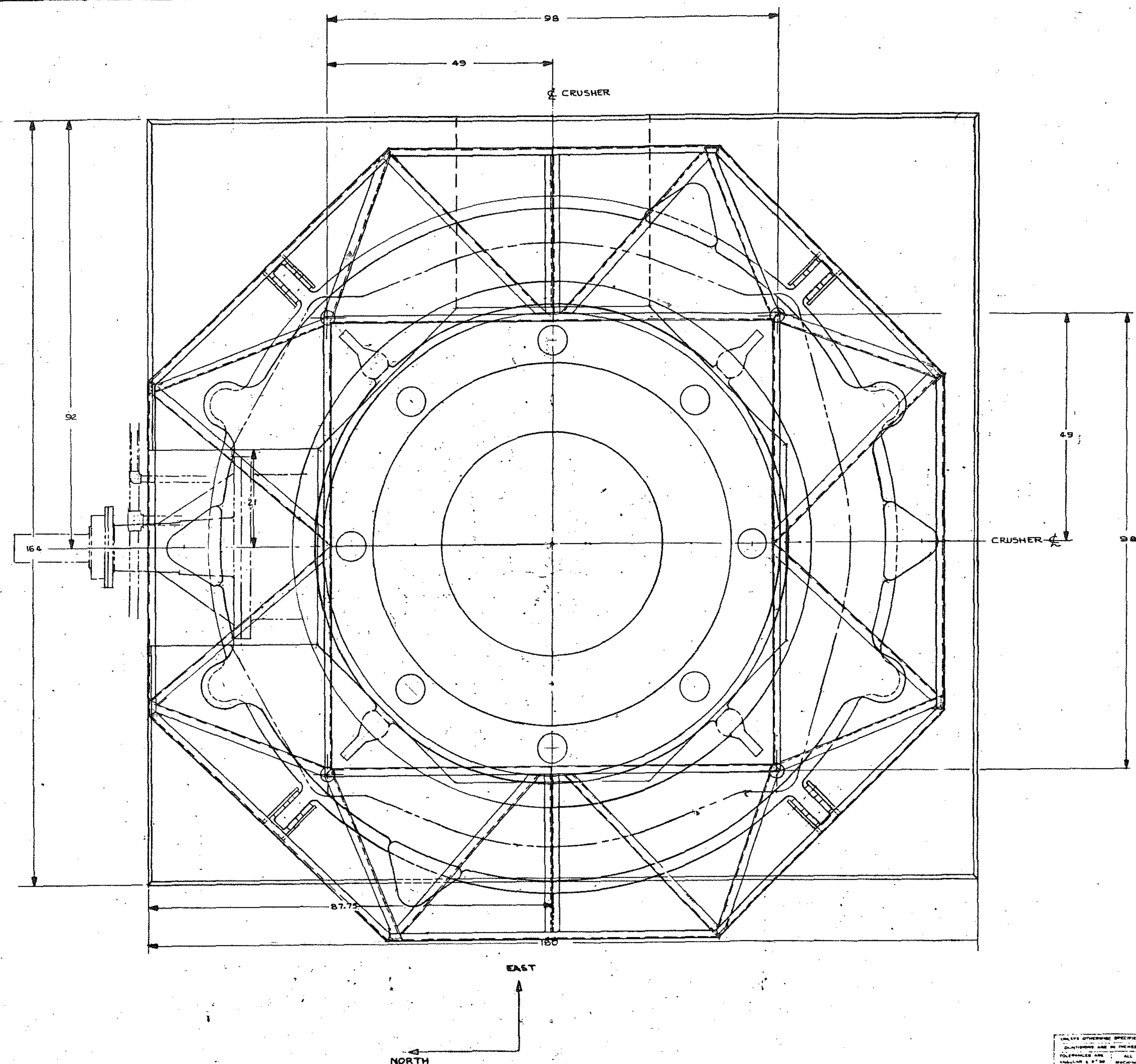
FRAMEWORK
SOUTH & WEST
ELEVATIONS

AEROPHYSICS
COMPANY

SK 72-100

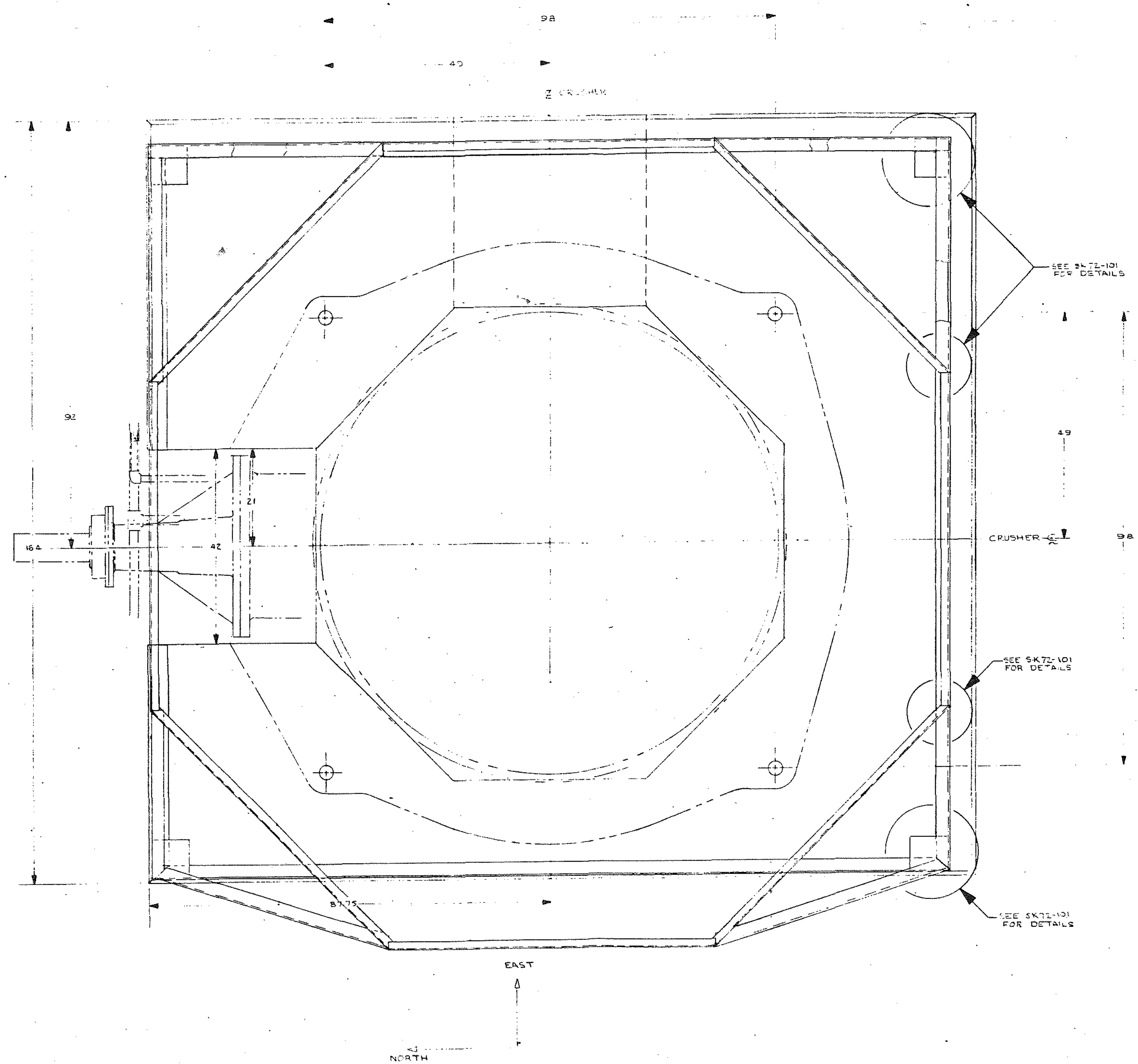
2


FOR DETAILS SEE SHEET 7
OCTAGONAL FRAMEWORK
LOWER STRUT SUPPORT
FOR DETAILS SEE SK 72-101
BASE ANGLE
BASE ANGLE
42
27
42
42
DRIVE MOTOR
66.69
NORTH ELEVATION
EAST ELEVATION
ELEVATIONS
SK72-100

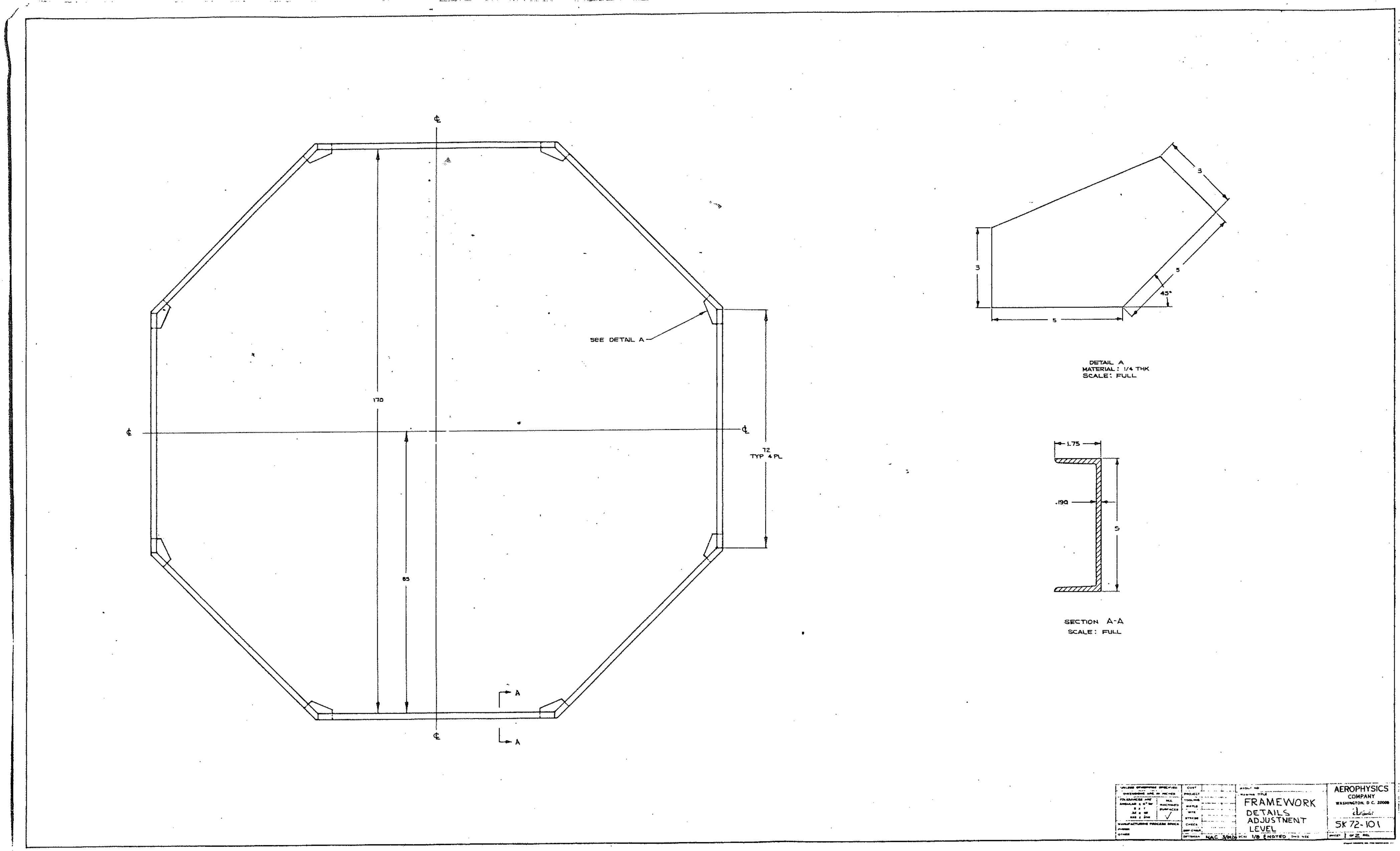


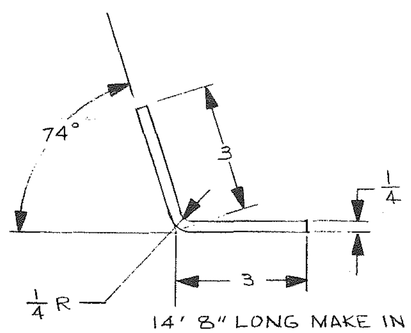
SEE SK 72-102 FOR DETAILS & ASSY

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	DRAWING TITLE: FRAMEWORK UPPER DECKING	AEROPHYSICS COMPANY WASHINGTON, D.C. 20008
		SK72-100
	SCALE / DWG SIZE	SHEET 4


98
49
CRUSHER
SEE SK72-101 FOR DETAILS
92
49
21
42
CRUSHER
98
SEE SK72-101 FOR DETAILS
SEE SK72-101 FOR DETAILS
87.75
EAST
NORTH

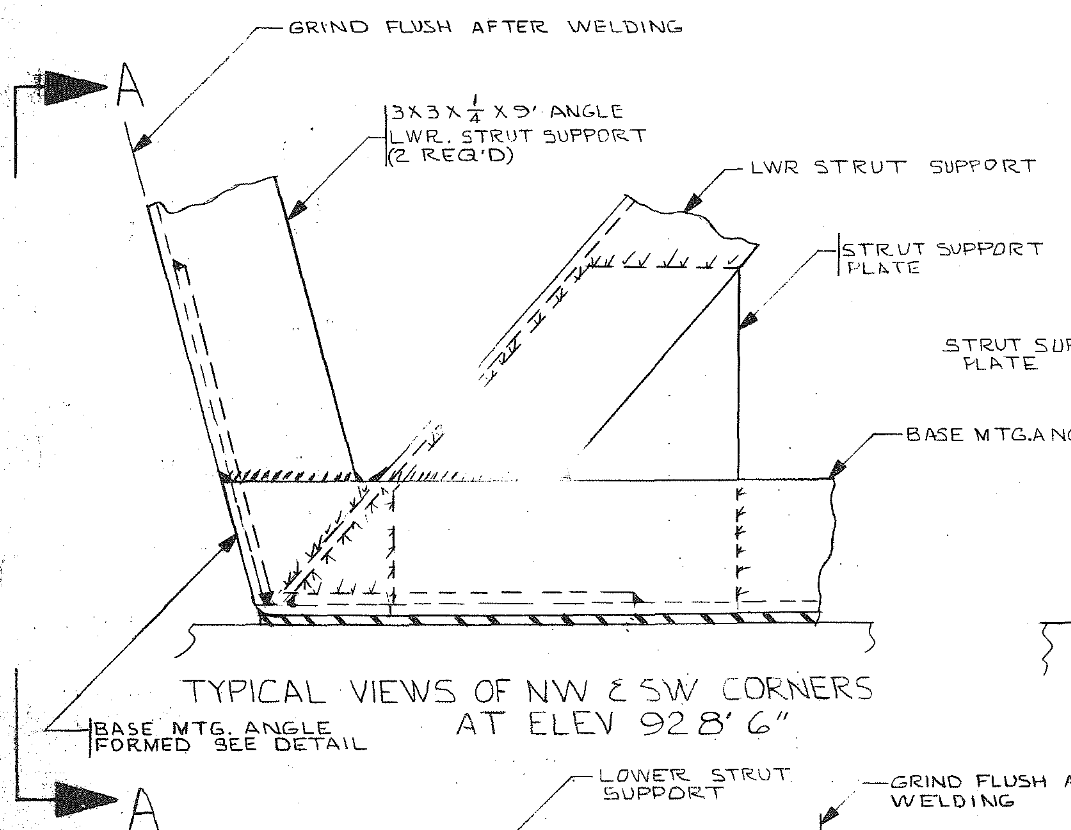
EL 928' 6"


℄
170
85
SEE DETAIL A
72
TYP 4 PL
A
A
3
3
5
5
45°
DETAIL A
MATERIAL: 1/4 THK
SCALE: FULL
1.75
.190
5
SECTION A-A
SCALE: FULL
FRAMEWORK
DETAILS
ADJUSTNENT
LEVEL
NAC
1/8 & NOTED
AEROPHYSICS
COMPANY
WASHINGTON, D.C. 20009
SK 72-101
SHEET 1 OF 2

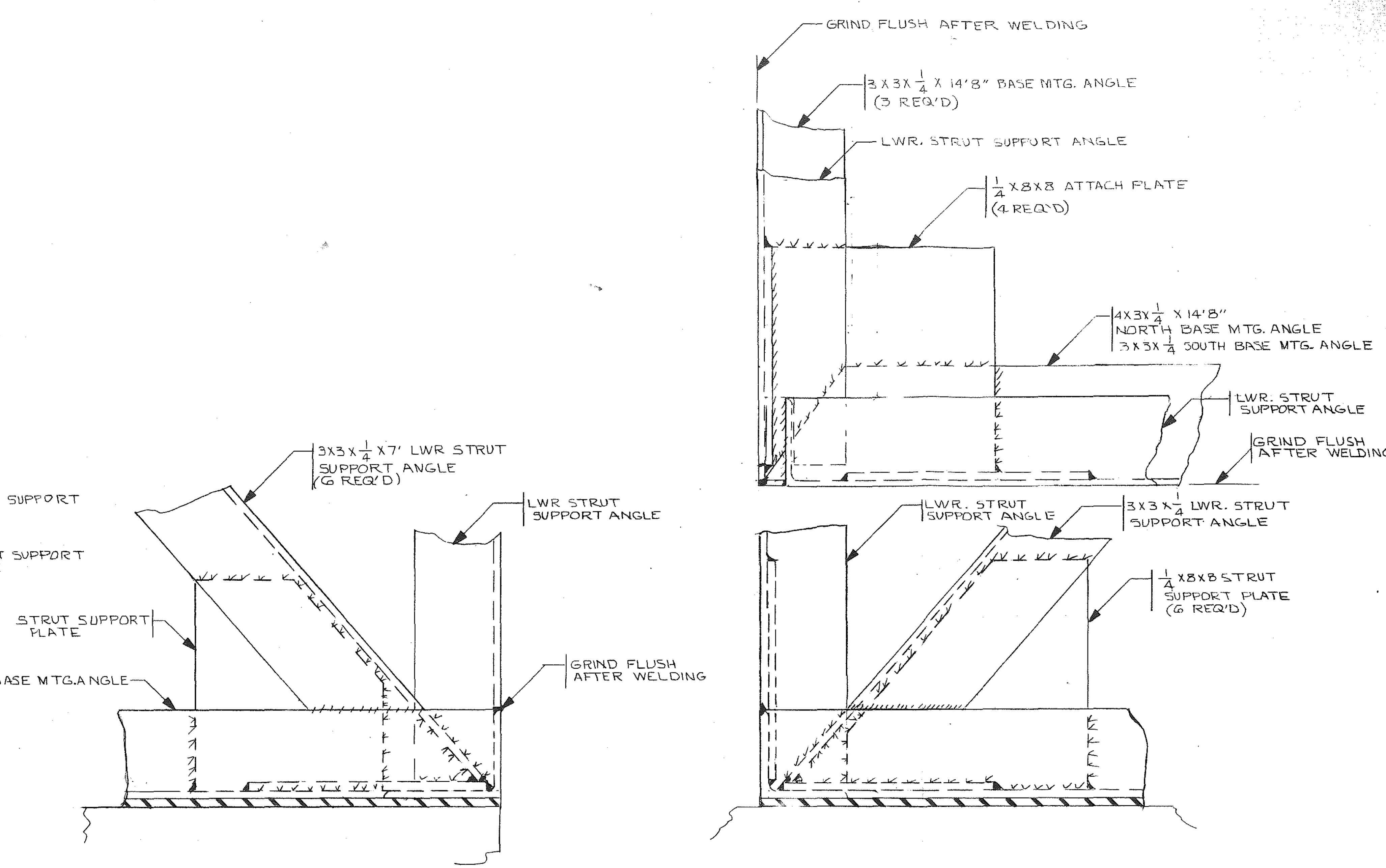


14' 8" LONG MAKE IN 2 SEGMENTS & WELD

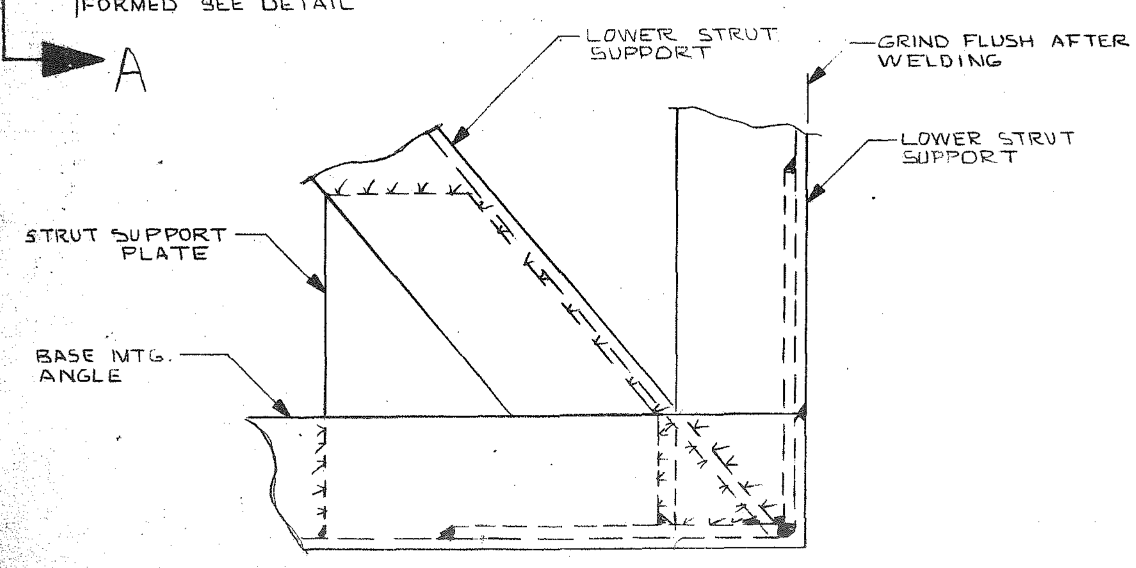
DETAIL BASE MTG. ANGLE



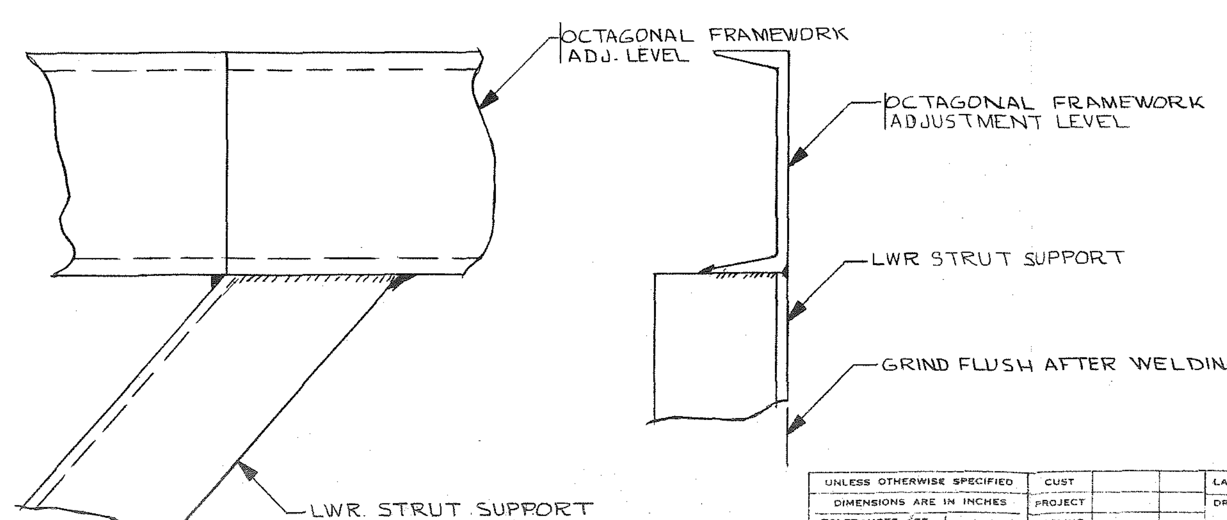
TYPICAL VIEWS OF NW & SW CORNERS AT ELEV 928' 6"



TYPICAL VIEWS OF NE & SE CORNERS AT ELEV. 928' 6"



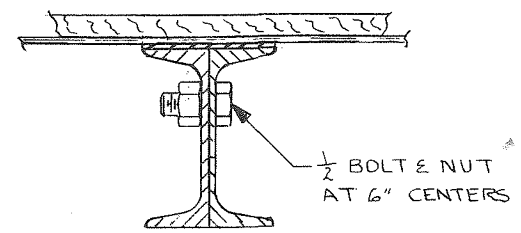
A-A



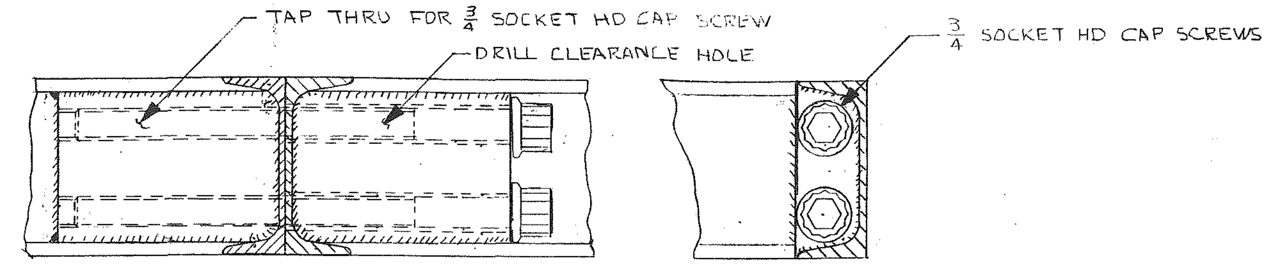
TYP. ATTACH 8 PLACES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CUST PROJECT	LAYOUT NO. DRAWING TITLE	AEROPHYSICS COMPANY WASHINGTON, D.C.
TOLERANCES ARE: ANGULAR ± 0° 30' .X ± .1 .XX ± .03 .XXX ± .010 / ALL MACHINED SURFACES √	TOOLING MATLS WTS STRESS	FRAMEWORK BASE DETAILS	
MANUFACTURING PROCESS SPECS FINISH OTHER	CHECK ENGR DFTSMAN	SCALE 1/8 / 1 · DWG SIZE	SK 72-[illegible] SHEET 2 [illegible]

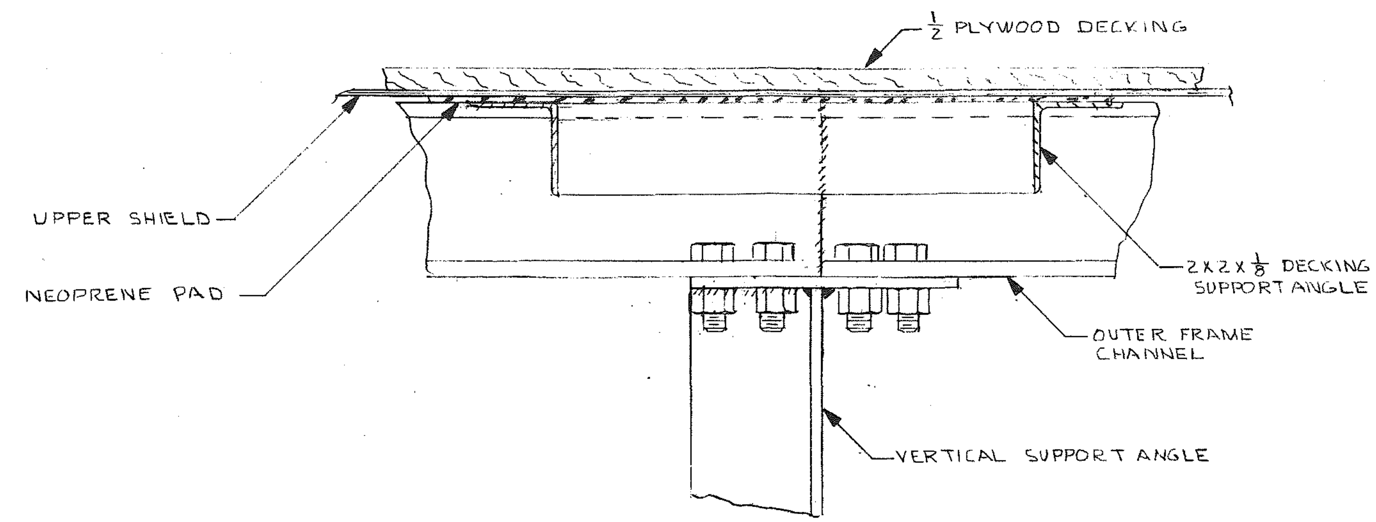
SK 55-105

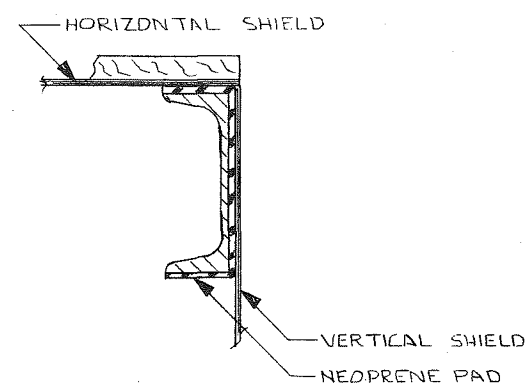


TYP AT SEPERATION

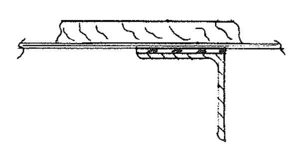


TYP SECTION OF INNER & OUTER SEPERATION
(TYP. 4 PLACES)

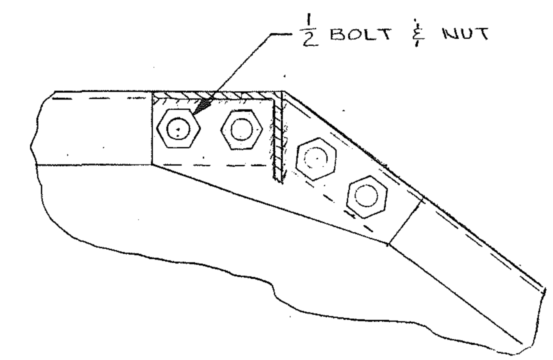




TYP. OUTER FRAME



TYP FLOOR SUPPORT



TYP AT OUTER CORNERS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE: ANGULAR ± 0° 30' .X ± .1 .XX ± .03 .XXX ± .010
ALL MACHINED SURFACES √
MANUFACTURING PROCESS SPECS
FINISH
OTHER

CUST / PROJECT / TOOLING / MATLS / WTS / STRESS / CHECK / GRP-ENGR / DFTSMAN

LAYOUT NO
DRAWING TITLE
UPPER DECKING DETAILS

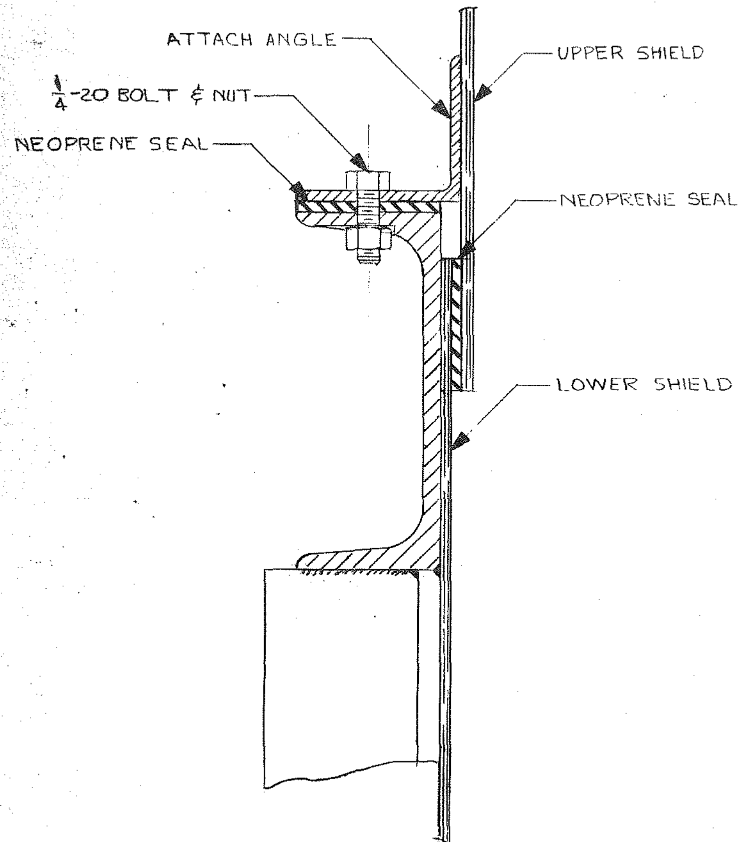
SCALE | DWG SIZE

AEROPHYSICS COMPANY
WASHINGTON, D.C. 20006

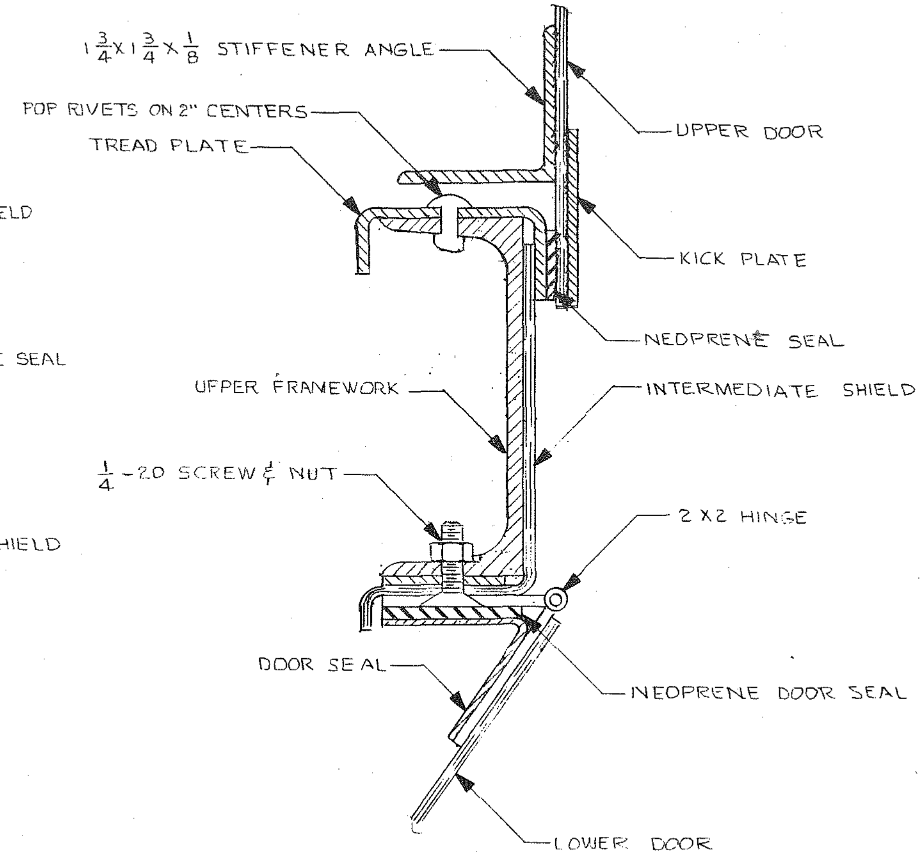
SK 72-102

SHEET OF

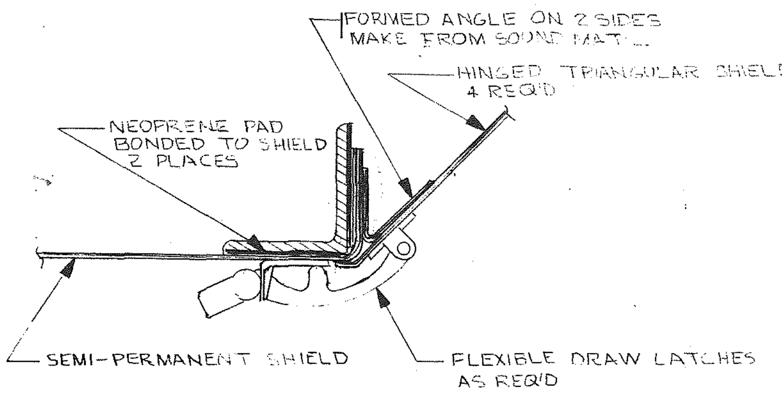
SK 72-103



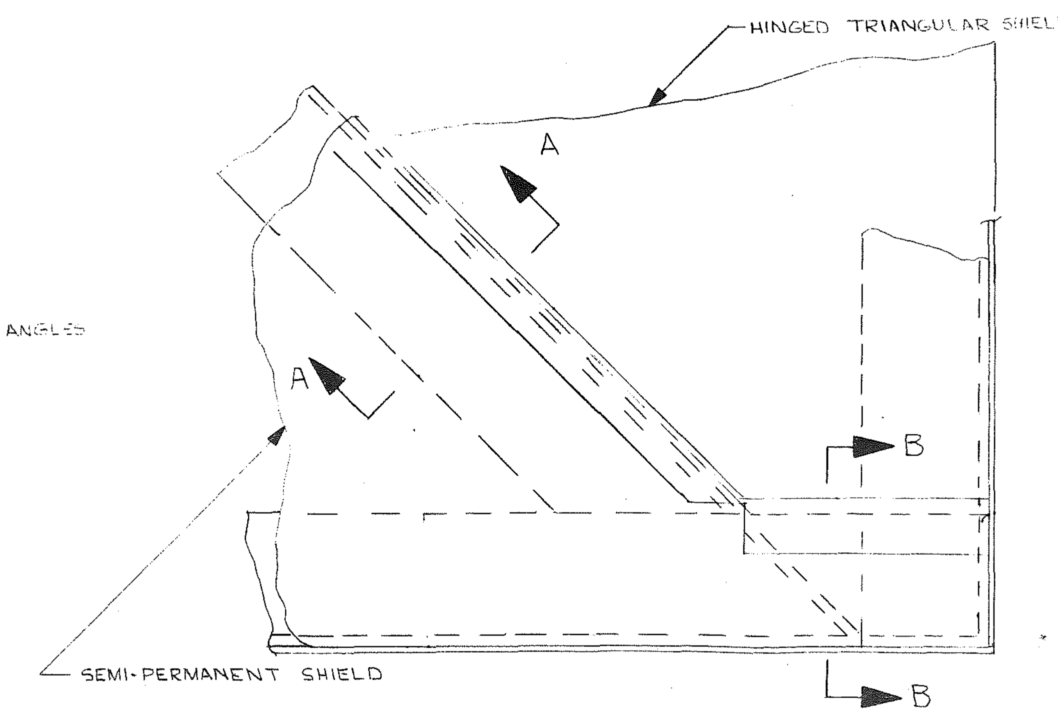
ATTACHMENT UPPER & LOWER
SEMI-PERMANENT SHIELDS
FULL SIZE



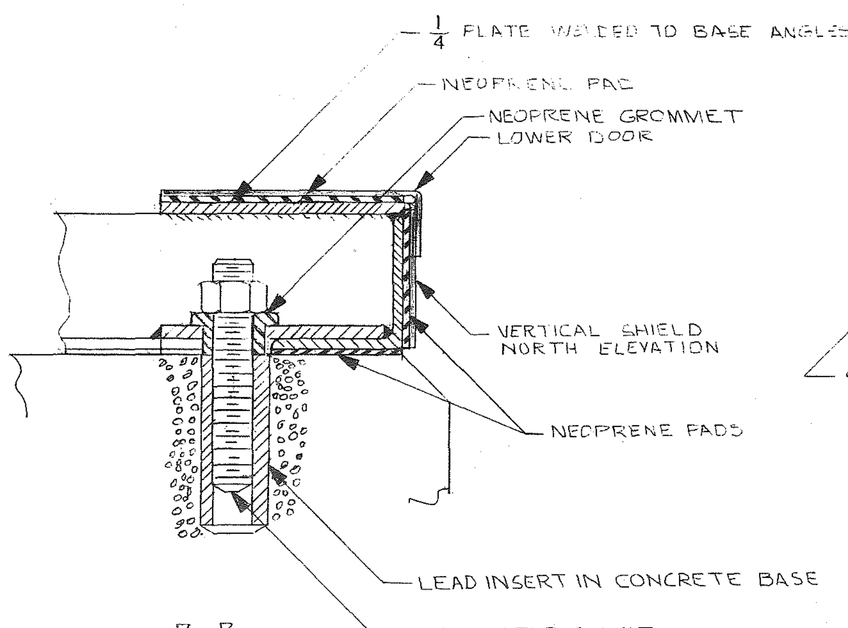
UPPER ATTACHMENT LOWER DOOR
LOWER SEAL UPPER DOOR
FULL SIZE



A-A

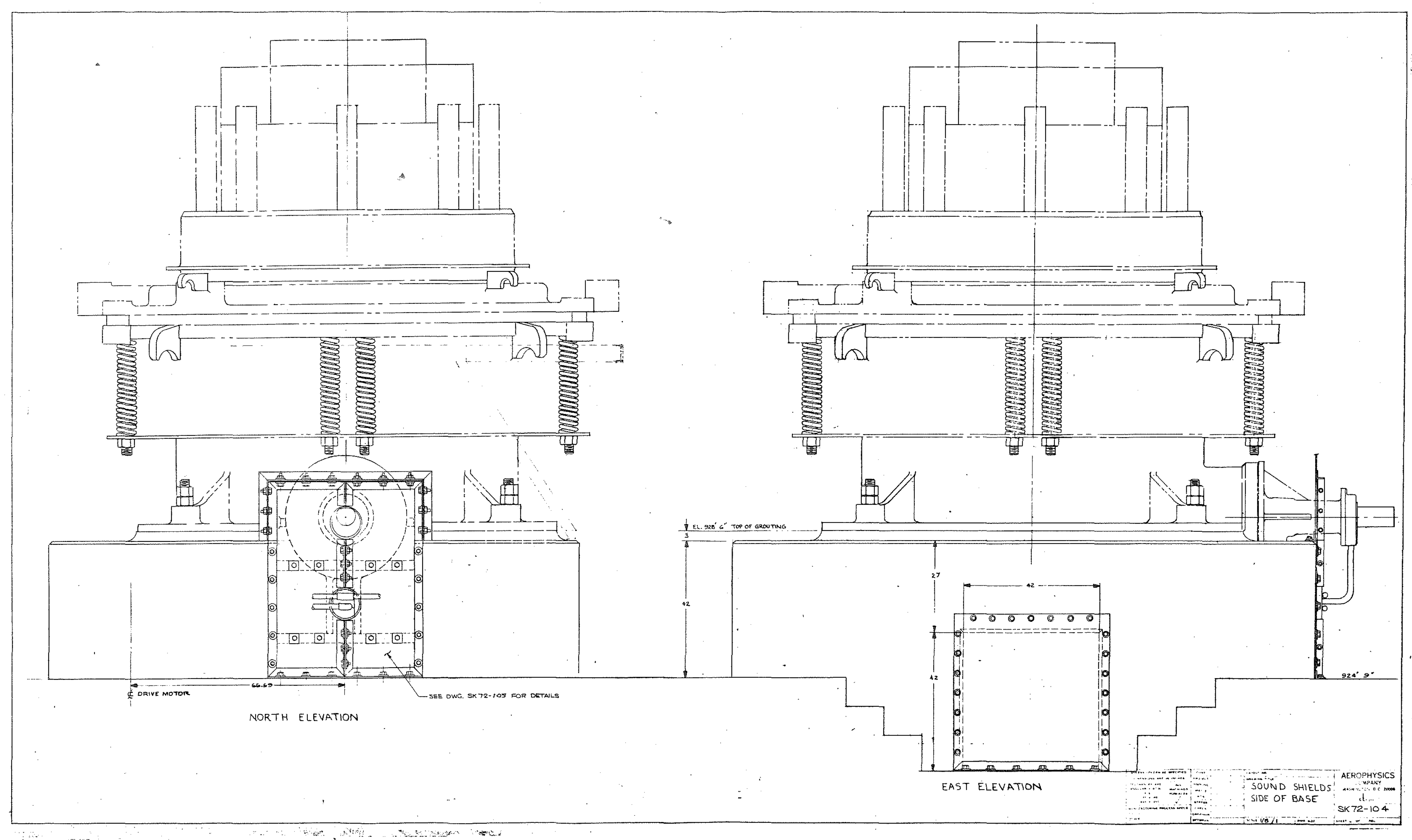


BOTTOM DOOR

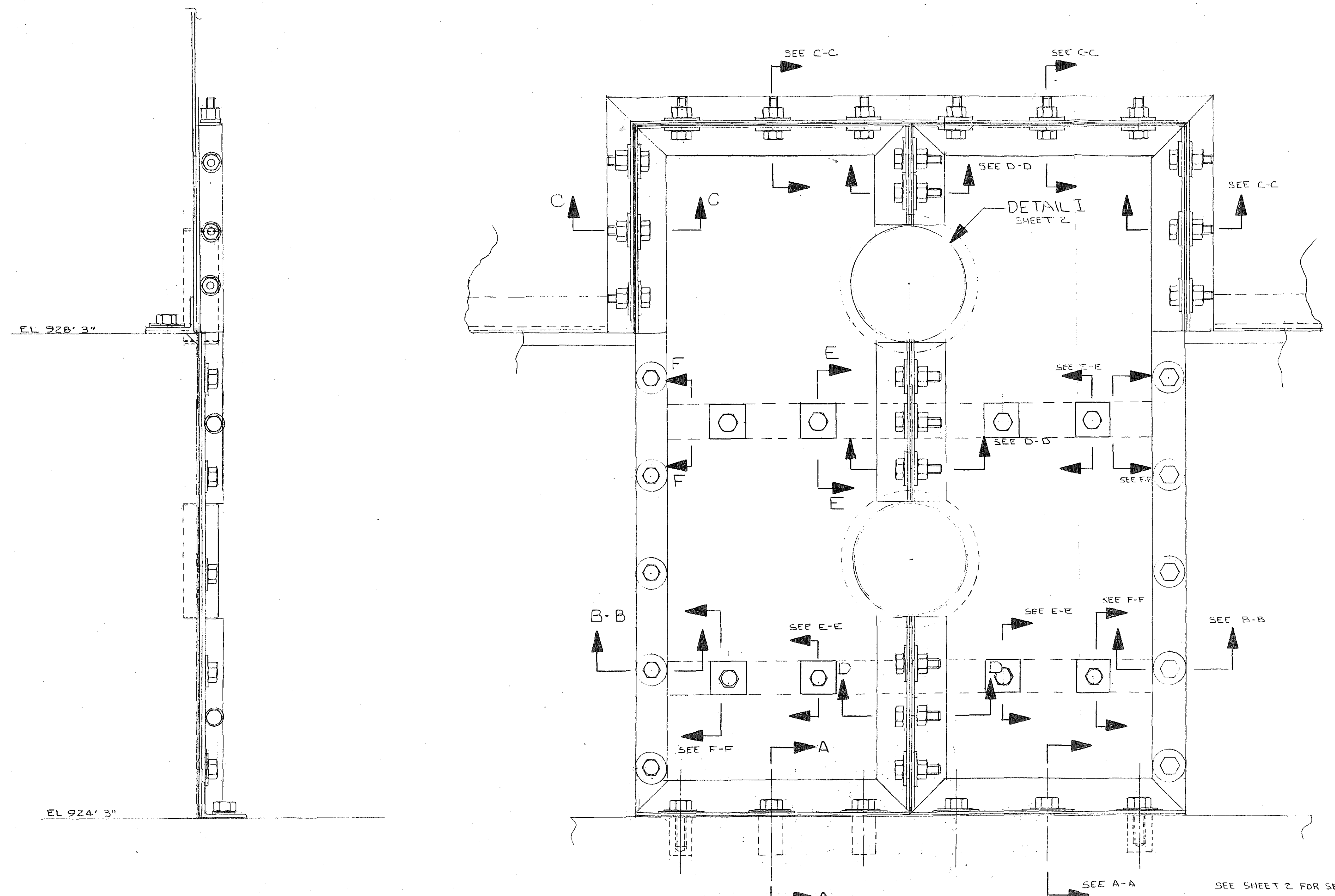


B-B

UNLESS OTHERWISE SPECIFIED	CUST	LAYOUT NO.	AEROPHYSICS COMPANY WASHINGTON, D.C.
DIMENSIONS ARE IN INCHES	PROJECT	DRAWING TITLE	
TOLERANCES ARE: ANGULAR ± 0° 30' .X ± .1 .XX ± .03 .XXX ± .010 — ALL MACHINED SURFACES √	TOOLING / MATLS / WTS / STRESS	ASSY & INSTALL SOUND SHIELD LOWER SECTION	
MANUFACTURING PROCESS SPECS	CHECK		SK 72-103
FINISH	GRP. ENGR		
OTHER	DFTSMAN	SCALE 1/2 — DWG SIZE	SHEET

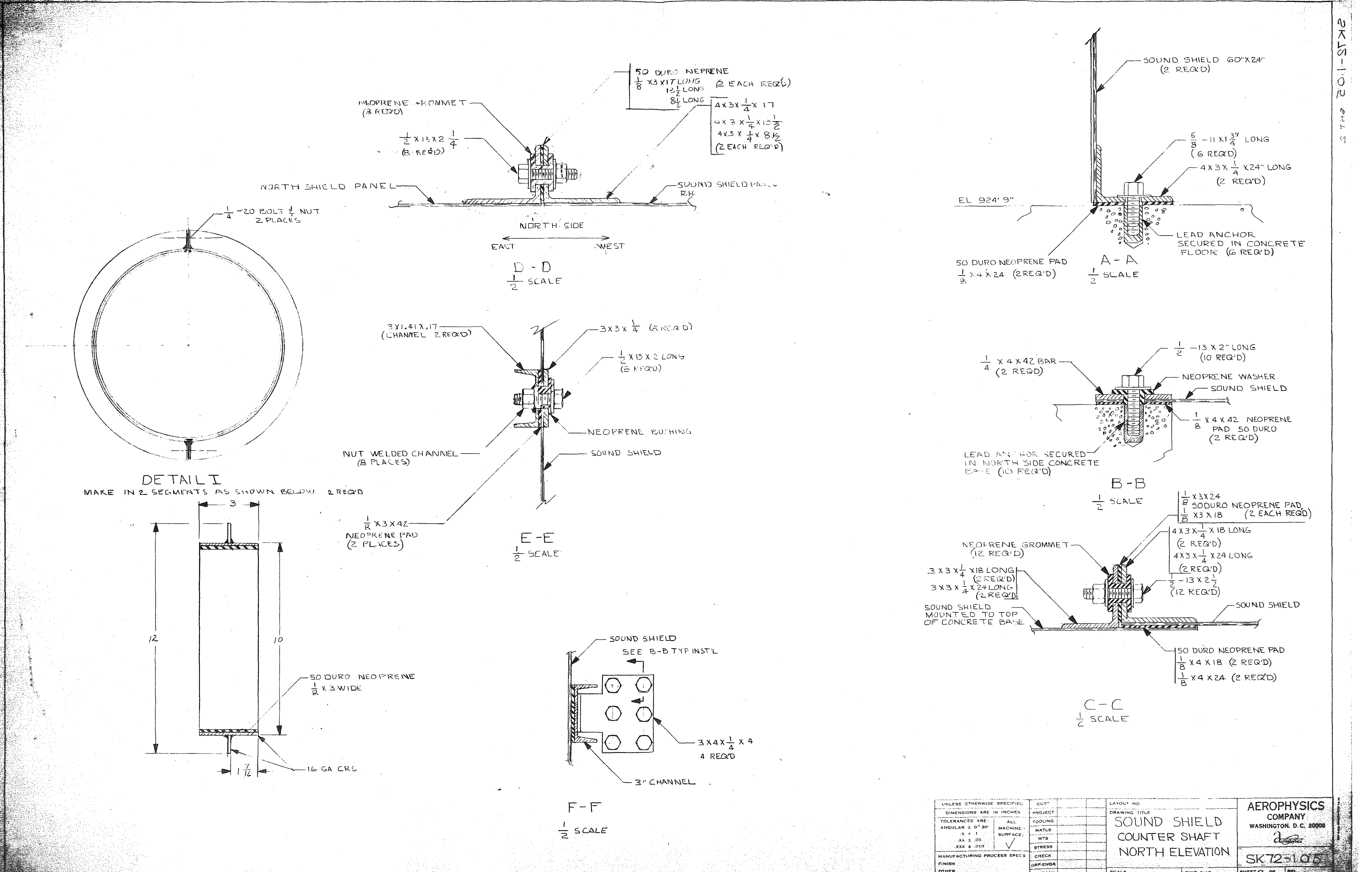


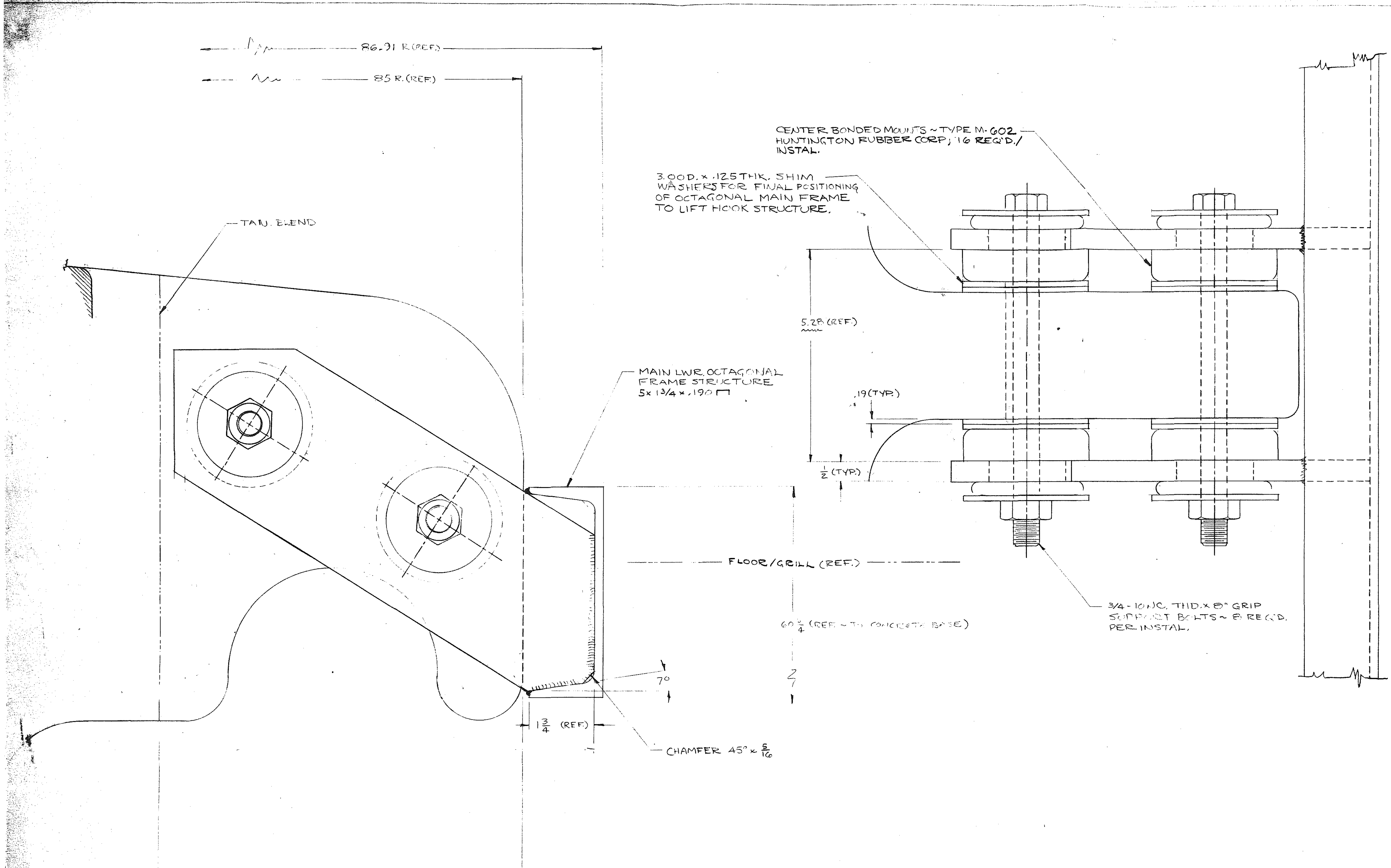
EL. 928' 6" TOP OF GROUTING
3
27
42
42
42
924' 9"
DRIVE MOTOR
66.69
SEE DWG. SK72-103 FOR DETAILS
NORTH ELEVATION
EAST ELEVATION
SOUND SHIELDS
SIDE OF BASE
AEROPHYSICS
COMPANY
WASHINGTON, D.C. 20006
SK72-104
SCALE 1/8 /1



SEE SHEET 2 FOR SECTION VIEWS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CUST	LAYOUT NO.	AEROPHYSICS COMPANY WASHINGTON, D.C. 20008
TOLERANCES ARE: ANGULAR ± 0° 30' .X ± .1 .XX ± .03 .XXX ± .010 — ALL MACHINED SURFACES √	PROJECT / TOOLING / MATLS / WTS / STRESS	DRAWING TITLE: COUNTER SHAFT NORTH ELEVATION SOUND SHIELD	SK 72-105
MANUFACTURING PROCESS SPECS FINISH OTHER	CHECK / GRP-ENGR / DFTSMAN	SCALE 1/4 — DWG SIZE	SHEET 1 OF 2


50 DURO NEPRENE
1/8 X3X17 LONG (2 EACH REQ'D)
13 1/2 LONG
8 1/2 LONG
4X3X 1/4 X 17
4X3 X 1/4 X 13 1/2
4X3 X 1/4 X 8 1/2
(2 EACH REQ'D)
NEOPRENE GROMMET (3 REQ'D)
1/2 X 13 X 2 1/4 (8 REQ'D)
NORTH SHIELD PANEL
SOUND SHIELD PANEL R.H.
NORTH SIDE
EAST
WEST
D - D
1/2 SCALE
1/4 -20 BOLT & NUT 2 PLACES
DETAIL I
MAKE IN 2 SEGMENTS AS SHOWN BELOW 2 REQ'D
3
12
10
50 DURO NEOPRENE
1/8 X 3 WIDE
1 7/16
16 GA CRS
3X1.41X.17 (CHANNEL 2 REQ'D)
3X3X 1/4 (8 REQ'D)
1/2 X 13 X 2 LONG (8 REQ'D)
NEOPRENE BUSHING
NUT WELDED CHANNEL (8 PLACES)
SOUND SHIELD
1/8 X3X42 NEOPRENE PAD (2 PLACES)
E - E
1/2 SCALE
SOUND SHIELD
SEE B-B TYP INST'L
3X4X 1/4 X 4
4 REQ'D
3" CHANNEL
F - F
1/2 SCALE
SOUND SHIELD 60"X24" (2 REQ'D)
5/8 -11 X 1 3/4" LONG (6 REQ'D)
4 X 3 X 1/4 X24" LONG (2 REQ'D)
EL 924' 9"
LEAD ANCHOR SECURED IN CONCRETE FLOOR (6 REQ'D)
50 DURO NEOPRENE PAD
1/8 X 4 X 24 (2 REQ'D)
A - A
1/2 SCALE
1/2 -13 X 2" LONG (10 REQ'D)
1/4 X 4 X 42 BAR (2 REQ'D)
NEOPRENE WASHER
SOUND SHIELD
1/8 X 4 X 42 NEOPRENE PAD 50 DURO (2 REQ'D)
LEAD ANCHOR SECURED IN NORTH SIDE CONCRETE BASE (10 REQ'D)
B - B
1/2 SCALE
1/8 X3X24
50DURO NEOPRENE PAD
1/8 X3 X 18 (2 EACH REQ'D)
4X3X 1/4 X 18 LONG (2 REQ'D)
4X3X 1/4 X 24 LONG (2 REQ'D)
NEOPRENE GROMMET (12 REQ'D)
3X3X 1/4 X18 LONG (2 REQ'D)
3X3X 1/4 X24 LONG (2 REQ'D)
1/2 -13 X 2 1/2 (12 REQ'D)
SOUND SHIELD MOUNTED TO TOP OF CONCRETE BASE
SOUND SHIELD
50 DURO NEOPRENE PAD
1/8 X4 X18 (2 REQ'D)
1/8 X4 X24 (2 REQ'D)
C - C
1/2 SCALE
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:
ANGULAR ± 0° 30'
.X ± .1
.XX ± .03
.XXX ± .010
ALL MACHINED SURFACE
MANUFACTURING PROCESS SPECS
FINISH
OTHER
CUST
PROJECT
TOOLING
MATLS
WTS
STRESS
CHECK
GRP-ENGR
DFTSMAN
LAYOUT NO.
DRAWING TITLE
SOUND SHIELD
COUNTER SHAFT
NORTH ELEVATION
SCALE
DWG SIZE
AEROPHYSICS COMPANY
WASHINGTON, D.C. 20009
SK72-105
SHEET 2 OF
REL
SK72-105



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CUST	LAYOUT NO.	AEROPHYSICS COMPANY WASHINGTON, D.C. 20008
TOLERANCES ARE: ANGULAR ± 0° 30' .X ± .1 .XX ± .03 .XXX ± .010 — ALL MACHINED SURFACES √	PROJECT / TOOLING / MATLS / WTS / STRESS	DRAWING TITLE: FRAMEWORK STABILIZING FORK	
MANUFACTURING PROCESS SPECS	CHECK		SK72-106
FINISH	GRP.ENGR		
OTHER	DFTSMAN WAF 3-11-77	SCALE FULL — DWG SIZE	SHEET 1 OF 1 — REL