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AUTHORITY

QMRTEC D/A LTR 22 SEP 1967

~~PART III~~

Upper case

An Evaluation of the Source

AND

Source Handling Equipment for the FOOD PROCESS DEVELOPMENT IRRADIATOR.

PART III.

of the
Quartermaster Radiation Laboratory
Natick, Massachusetts

(11) Jul 61

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(5) Quartermaster Research and Engineering Command, Natick, Mass.

QM RESEARCH AND ENGINEERING COMMAND
QUARTERMASTER CORPS, U.S. ARMY

EVALUATION OF THE

COBALT 60 SOURCE AND SOURCE HANDLING SYSTEM

for the

QUARTERMASTER RADIATION LABORATORY

at

Natick, Massachusetts

Prepared by

Headquarters
Quartermaster Research and Engineering Command
Natick, Massachusetts

July 1961

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PREFACE

General

The Quartermaster Radiation Laboratory, to be constructed at Natick, Massachusetts, will include a megacurie cobalt 60 source and a 24 Mev 18 kw linear electron accelerator. The purpose of this laboratory, scheduled for completion during late summer of 1962, is to provide irradiation services for the further study of the radiation processing of foods. The QMRL will represent a major advance in the techniques of using ionizing radiation and will hasten the time when radiation processed foods play their full part in both the military and civilian economies.

The QMRL is a modification of the High Intensity Food Irradiator (HIFI) to have been built by the Army at Stockton, California. In the fall of 1959, after evaluation within Army Research and Development, it was determined that the construction of the HIFI pilot plant was premature and that further research should continue. To aid in this research, the QMRL would be constructed to provide radiation services over a wide range of doses and conditions to various food products.

The Army's Revised Program, including the development of a concept for this facility, began in March 1960. The Curtiss-Wright Corporation, selected as prime contractor for the

HIFI project, began design studies to develop a cobalt 60 irradiator of greater flexibility than that of the previously planned production facility. Work on HIFI had focused attention on several general problems connected with the construction of a food radiation processing plant. These included problems of microbiological safety, depth dose uniformity, product quality control, and product evaluation.

The design of an irradiator of sufficient flexibility to permit the evaluation and practical solution of such problems became a requirement of the QMC Food Preservation Program.

This objective has been achieved by a complete redesign of source configuration and handling techniques to permit a wide variety of source distributions to be assembled and tested. This has necessitated a renewed study of the optimum method of encapsulation for the rod sources which are now to be utilized in place of the plaque source originally intended for HIFI.

This report considers in detail only the cobalt source, method of encapsulation, source handling mechanisms, pre- and post activation testing procedures and results, and an analysis of potential source hazards. It is realized that only through the recognition of potential problems, with tentative solutions and means to compensate for or overcome them, can this megacurie source be safely used. As long as control is maintained over these problem areas, it is felt that this source can adequately meet our needs.

<u>Facility Concept</u>

The QMRL will be a functional single-story permanent type building consisting essentially of a food processing area, radiation areas, laboratory area, and administrative area. Figure 3-0 shows the general floor plan.

In addition to the required food processing equipment, the food processing area will contain necessary receipt, transfer and storage facilities to accommodate both fresh and radiation processed foods.

The radiation areas will contain the cobalt 60 gamma source, referred to as the Food Process Development Irradiator (FPDI), and a linear electron accelerator source, referred to as LINAC.

The laboratory area will contain those facilities necessary to adequately control food processing, operational safety, health physics, and dosimetry.

The FPDI will utilize a conveyor operation to expose the food to radiation. Products to be radiation processed will be in a variety of containers, ranging from cans to flexible films and crates. Meat products will constitute nearly 100% of food items to be processed, at least for the first year or so of operation.

The design and operation of the QMRL is predicated on the facility's ability to adequately fulfill the radiation requirements of the United States Army's Quartermaster Corps in its endeavor to successfully develop the art of radiation sterilization of foods.

I. INTRODUCTION

The bulk of the material relating to the source and source handling equipment has been developed by the Curtiss-Wright Corporation, Princeton Division. Much of the information contained herein, including the engineering drawings, has been taken from the Final Design Report of the Food Process Development Irradiator, January 31, 1961, accomplished under contract between Curtiss-Wright and the Atomic Energy Commission. Other drawings and data were taken from the Title I Report, Preliminary Design Report on Quartermaster Radiation Laboratory accomplished under contract between Associated Nucleonics, Inc., and the United States Atomic Energy Commission.

The megacurie cobalt 60 source to be used in the QMRL was developed by the Curtiss-Wright Corporation in conjunction with duPont and the Savannah River Operations Office of the Atomic Energy Commission. The source consists of 392 cobalt cylinders, clad first in stainless steel and then in aluminum. Both jackets are applied prior to reactor activation; hence close tolerances are required to insure acceptable activation results.

After arrival at the Radiation Laboratory, the slugs are arranged in one of several possible source arrays, and assembled onto the source platform. Normal storage is in a 24 foot pool located in the radiation chamber of the Laboratory. Product irradiation is accomplished by raising the source elevator platform until the source is above water, and subjecting the conveyor-carried product to the radiation until the desired dose is attained. A continuous radiation process is thus possible utilizing this procedure.

Presented in this portion of the report are the design data relating to the source and source handling mechanisms. Included is an evaluation of the cobalt source system from the standpoints of both operational adequacy and of operational safety.

Certain control measures must be constantly monitored and both real and potential problem areas carefully analyzed to insure satisfactory source performance. This will be especially true during the initial and early operation of the facility. However, to recognize possible danger areas and to cope with them is to insure the successful operation and use of this source.

II. RADIATOR DESIGN

The parameters for this item are set by the performance specifications included as Table II-1. The principal changes from the H.I.F.I. specification are an increase in the maximum acceptable dwell time to 77 minutes, and a reduction in the capacity to 100 pounds per hour at a dose of 5 megarad. It remained necessary to provide for the accommodation of bulky items of up to 30 cubic feet.

To meet these requirements, it was decided to carry out sterilizing irradiations as a batch operation, using a two plaque array of sources and a rapid conveyor for introducing and removing the packages. The specified conditions of dose, dose rate and dose uniformity require that a source of approximately one megacurie be used despite the low throughput. The use of a batch system is proposed in order to circumvent the problems arising from the possibility of movement of micro-organisms during irradiation.

(When sterilizing containers of a fluid medium by moving them continuously through a non-homogeneous radiation field, it is conceivable that micro-organisms may migrate to the point of lowest radiation intensity and remain there even though it occupies different positions within the container as it moves past the source. These micro-organisms would thus receive less than the average dose for the whole container and possibly less than the lethal dose. The 12% permissible variation in dose was defined by the possibility of a micro-organism moving a maximum distance of 6 inches, the diameter of a No. 10 can, while the can was being carried through a radiation field 50 inches long. For a specified dose of 5.0 Megarads such a micro-organism might receive a dose as little as 4.4 Megarads; or as high as 5.6 Megarads, if it migrated to the position of maximum radiation intensity.

If a package is moved quickly into a uniform radiation field, the problem is overcome, since there is no possibility of movement to a series of lowest dose regions during the effective irradiation period.)

It was obvious that no single fixed source configuration such as was proposed for the H.I.F.I. could satisfy the varied process development requirements of the new program. Furthermore, the reduced throughput requirement and the consequent but by no means proportionate reduction in the number of curies required made it possible to consider the relative advantages of other types of source elements. In particular, it was necessary to have a radiator which could readily be taken apart and re-assembled in a different configuration. This indicated the use of sections each of a sufficient curie strength to keep the numbers to a reasonable level, yet physically small enough for convenient handling. Rods and strips were each considered, with the former being preferred mainly because their symmetry would simplify source arrangement.

It was possible to use the information provided by previous experimental work carried out with assemblies of rod sources by Curtiss-Wright. These had included variable spacing between rods as well as between the center line of the rod array and the surface of the target package. Measurements of dose rates at successive depths were made in a manner similar to the experimental work reported in the H.I.F.I. Progress Reports and summarized in report No. 17.

One important conclusion to be drawn from this work is that except at short distances from the array (less than the spacing between rod centers) the radiation fields at a distance from an array of rods may be calculated assuming an equivalent plane source with the same activity per unit area. It is necessary to consider both the source and its cladding material as an equivalent absorber (mass per unit area) uniformly distributed over the whole array.

Plaque Size and Cobalt 60 Requirements

The plaque size is predicated on irradiating a batch of four cartons of No. 10 cans arranged as shown in Figure 3-1. This is the larger of the two package sizes given as alternatives in the specification.

Earlier work had confirmed that with an 11 inch spacing between the center line of a two plaque array, an overlap of the source beyond the target material of 8-1/2 inches (with no source shaping) is required to ensure the specified max./min. ratio. This requires an active height of 42.20 inches and an active length of 56.225 inches.

The dimensions of the cobalt 60 source rods were finally decided by agreement with personnel at the Savannah River Plant of the U. S. Atomic Energy Commission (Mr. J. W. Burch, Reactor Division). The preliminary design suggested individually encapsulated cobalt pieces about 10 inches long and 0.9 inches diameter with the cobalt diameter 0.6 inches and an activity per slug of about 3,000 curies.

However, Savannah River Operations Office pointed out that their required diameter for material to be inserted into the reactor is 0.940 ± .002 inches and it would be necessary to keep within these limits. This fixed the O.D. of the slugs. Their internal arrangement was again a compromise. In the preliminary design, single encapsulation in stainless steel had been suggested. This, however, was rejected by the Licensing Branch in Washington. They felt it would not be permissible to have, in a food plant, firstly bare stainless steel surfaces which had been exposed in a reactor and were, therefore, radioactive and secondly, singly encapsulated cobalt.

One of the major advantages of using separate rod sources was the possibility of pre-activation encapsulation, avoiding entirely the much more expensive hot cell work involved in post activation encapsulation. It was, therefore, decided to devise a double encapsulation technique using an inner capsule of stainless steel and an outer one of aluminum. Full details of this process are described in Section III.

The diameter of the cobalt rod itself was increased from the 0.6 inches originally suggested to 0.725 inches to insure a sufficient activity per unit length with the neutron flux and activation periods available in the Savannah River reactors.

From these considerations, the final size and the numbers of rods in the radiator plaques was settled as shown in Table II-2 and the dimensions of the individual source rods as shown in Table II-3. Four of the 10" encapsulated cobalt slugs will be stacked on end in an aluminum source holding tube as shown in Figure 3-2.

Actual Cobalt Requirement

It has been calculated that 1.1 M curies of cobalt 60 will be sufficient to meet the F.P.D.I. specifications. However, to compensate for production schedules, time delays prior to shipment, installation and test, it is necessary to plan for the production of a number of curies in excess of this. This may be estimated as follows:

Let us assume a requirement for 1.10 M curies on the date of handing over the facility to the Quartermaster Corps (D-Day). Present schedule calls for all cobalt to be delivered to Natick not later than 3 months perior to this date, (and for half of it to be delivered 5-1/2 months before D-Day). If the average time on site before D-Day is four months then the number of curies to be delivered is:

$$\frac{1.1 \times 1}{0.96} = 1.146 \text{ M Curies}$$

Further assuming that activation is spread uniformly over a 12 month period, we must allow for an average of 6 months decay in planning the activation, i.e.:

$$1.146 \times \frac{1}{0.94} = 1.22 \text{ M Curies}$$

(Assuming 1% per month decay)

Since the production estimate is only accurate to within $\pm$10%, to be sure of getting the required amount, we must add on 10%, i.e.:

$$1.22 \times \frac{1}{0.9} = 1.356 \text{ M Curies}$$

The planned activation must be for 1.356 M Curies.

In addition, it must be kept in mind that the F.P.D.I. design requires not less than 1.1 megacuries in 392 source slugs to meet the specifications. The source tubes and jig plate have been designed for this number.

Cobalt 60 Activity Required

Total Planned Activity	1.356×10^6 curies
Minimum Activity Handed Over to Q.M.	1.1×10^6 curies
No. of Slugs	392
Minimum Activity per Slug (as handed to Q.M.)	$\frac{1.1 \times 10^6}{392} =$ 2800 curies/slug

TABLE II-1

PERFORMANCE SPECIFICATIONS

1. Items to be exposed in the irradiation facility will require doses in the range from 8,000 to 5,000,000 rad.

2. Dwell time is to be minimized. The maximum acceptable dwell time for a dose of 5 megarad is 77 minutes.

3. The source should be capable of processing items of unit density at a rate of 100 pounds per hour at a dose of 5 megarad.

4. The radiation chambers should be designed to provide for the processing of items ranging in size from symmetrical units of 25 cu. in. to packages with maximum dimensions of 24" x 18" x 7 3/4". Smaller units may be assembled into packages of approximately the maximum dimensions. In addition, it should be possible to irradiate on a non-routine basis, items of 30 cubic feet. These items will not exceed 8 feet in length and a maximum thickness of 16 inches may be assumed.

5. Temperature of the radiation chamber should not exceed the ambient temperature by more than 10°F, except that provision shall be made to permit the chamber to be maintained at a minimum of 50°F during the heating season while providing adequate ventilation for ozone control.

6. Dose variation within packages is to be minimized. The maximum acceptable range of dose variation in a package of unit density is between 100 and 125% of the required amount in a package 6" x 18" x 22".

TABLE II-2

PLAQUE SIZE AND COBALT 60 REQUIREMENT

No. of Source Rods	2 x 49
Spacing of Rods	1.156 inches
Active Height of Plaque	42.20 inches
Actual Overall Height of 4 Slugs	42.60 inches
Active Length of Plaque	56.225 inches
Actual Overall Length of Plaque	56.625 inches
Center-Line Plaque Separation	11.0 inches
Free Space Between Plaques	9.875 inches

TABLE II-3

FINAL DIMENSIONAL SPECIFICATION FOR CO^{60} SLUGS

Length of Cobalt Rod	10.250 ± 0.002 inches
Diam. of Cobalt Rod	0.725 ± 0.0005 inches
I.D. of S. S. Capsule	0.725 ± 0.001 inches
O.D. of S. S. Capsule	0.765 ± 0.001 inches
Overall Length of S. S. Capsule	10.330 ± 0.002 inches
I.D. of Al Capsule	0.767 ± 0.001 inches
O.D. of Al Capsule O.D. of Slug	.943 ± 0.002 inches
Overall Length of Al Capsule Overall Length of Slug	10.699 ± 0.005 inches

For details, see drawing 3-3.

CALCULATION OF EQUIVALENT ABSORBER THICKNESS OF THE COBALT SLUGS

Let μ = Source Absorption Coefficient

X_s = Source Thickness

ρ = Density

Equivalent absorber thickness $= \mu X_s$

$$X_s = \mu \times \frac{\text{rod volume}}{\text{radiator area}}$$

$$= \mu \times \frac{\text{rod mass}}{\text{radiator area}}$$

Values of μ/ρ for 1.25 MeV photons for cobalt, stainless steel and aluminum may be taken as 0.0530, 0.0532 and 0.055 respectively.

For one rod, total mass = mass of the rod itself + mass of an equal length of guide tube.

Mass C_o = $10.25 \times \pi \times \frac{.725^2}{2} \times 16.39 \times 8.7 = 604$ gms.

Mass S. S. Cladding = $10.29 \times 0.20 \times \pi \times 0.745 \times 16.39 \times 7.96$
= 63 gms.

Mass Al Cladding = $10.65 \times 0.87 \times \pi \times 0.852 \times 16.39 \times 2.70$
= 110 gms.

Mass Al Guide Tube = $10.65 \times 0.065 \times \pi \times 1.06 \times 16.39 \times 2.70$
= 102 gms.

Effective slug area = $10.65 \times 1.156 \times 6.45 = 794$ cm^2

$$\mu X_s = \frac{(0.053 \times 604) + (0.0532 \times 63) + (0.055 \times 212)}{79.4}$$

$$= \frac{32 + 3.4 + 11.7}{79.4}$$

$$= \frac{47.1}{79.4} = 0.594$$

and $\frac{\mu X_s}{2} = 0.297$

(Since for the water absorber $\mu X = 0.160$ per inch, for a 3 inch water absorber, the total equivalent absorber at that depth (i.e., midpoint of a 6 inch package) will be $0.297 + 0.480 = 0.777$ with respect to radiation incident from either side, and 0.297 and 1.257 for the front and rear absorber surfaces respectively.)

Dose Rate and Dwell Time (Using H.I.F.I. experimental data)

Now the closely spaced rod source under the conditions of the F.P.D.I. will give rise to essentially similar radiation fields to that from a HIFI type plaque normalised to one curie per unit surface area. Thus we may use the experimental curves shown in Figure II-29 of the HIFI report (now Page 13) to derive values for the max:min. ratio and y the geometry factor (M_{rad}/hr per curie/cm^2).

Hence we get a maximum:minimum ratio of 1.21 and geometry facter 6.0×10^4 rad/hr per curie/cm^2.

If we assume that the whole 1.1 M curies is evenly distributed over the active area of the plaque array, we get a value for the activity density S_a in curies per cm^2

$$S_a = \frac{1.1 \times 10^6}{42.2 \times 56.2 \times 6.45 \times 2} \text{ curies/cm}^2\text{/plaque}$$

$$= 35.9 \text{ curies/cm}^2 \text{ in each plaque}$$

Since there is an activity density of 35.9 curies/cm^2 in each plaque, we get a dose rate at the center of a 6" water slab.

$$\text{Dose Rate} = 2 \times 35.9 \times 6.0 \times 10^4 \text{ Mrad/hr.}$$

$$= 4.31 \text{ Mrad/hr.}$$

and the dwell time for 5 Mrad becomes 69.5 minutes plus 4 minutes transport time or 73.5 minutes portal to portal.

Dose Rate and Dwell Time by Calculation

It was shown in Section II of HIFI report No. 17 (p. 17 and graphs II 41 and II 42) that the depth dose distribution opposite a finite plane source could be obtained by calculation. Several methods were referenced and that giving the best approximation was as follows (Eqn 3 p. 15 HIFI report No. 17)

$$D = 2\pi\omega k \quad E_1(\mu X) \; B(\mu X) \times S_a \text{ - - - } \quad (1).$$

where D = dose rate in rad/hr

= $2\pi^{-1}$ x solid angle in steradians subtended by a rectangle of width W and length L at a distance Z from its midpoint

k = conversion factor to dose rate units

$$= \frac{3.7 \times 10^{10} \times 1.602 \times 10^{-6} \times 3600\, E_o}{4 \times 100} \quad \text{rad/hr per curie/cm}^2$$

= 1.26×10^4 for a Co^{60} source and water

μ_a = absorber absorption coefficient

ρ_a = absorber density

S_a = activity density of the source curies.cm^{-1}

$E_1(\mu x)$ = First order exponential integral

$B(\mu x)$ = Build up factor

We can now obtain values of ω from page 15 (previously II 41) for points in the mid plane of a 6 inch target on the front face, center and rear face, with respect to either of the source plaques.

For the front surface $\frac{Z}{1/2\, L} = \frac{2.5 \times 2}{56.2} = 0.089$

For the mid point $\frac{Z}{1/2\, L} = \frac{5.5 \times 2}{56.2} = 0.196$

For the rear surface $\frac{Z}{1/2\, L} = \frac{8.5 \times 2}{56.2} = 0.302$

From Figure 5, the corresponding values of ω may be read off. For the array dimensions we have

$$\frac{W}{L} = \frac{42.2}{56.2} = 0.75$$

$$\omega_F = 0.91$$

$$\omega_M = 0.79$$

$$\omega_R = 0.69$$

Now at each of these points, the equivalent absorber thickness is

Front	0.297
Mid	0.297 + 3 x .160 = 0.777
Rear	0.297 + 6 x .160 = 1.257

Hence from Figure II-6 (now page 14) we can obtain values for the overall attenuation factor $E_1(\mu x) \cdot B(\mu x)$ for each of these equivalent absorbers.

These values are

$E_1(\mu x)\,B(\mu x)$	Front = 1.52		Rear = 0.57
	Mid = 0.92		

Inserting these figures in (1) for each of the three positions we get

$$D_F = 2\pi \times 0.91 \times 1.26 \times 10^4 \times 1.52 \times 35.9$$

$$= 3.94 \times 10^6 \text{ rad/hr}$$

$$D_M = 2\pi \times 0.79 \times 1.26 \times 10^4 \times 0.92 \times 35.9$$

$$= 2.06 \times 10^6 \text{ rad/hr}$$

$$D_R = 2\pi \times 0.69 \times 1.26 \times 10^4 \times 0.57 \times 35.9$$

$$= 1.12 \times 10^6 \text{ rad/hr}$$

Since what is the front surface of the target with respect to one source array is also the rear surface with respect to the other array, the total dose rate for the mid point on the surface will be the sum of D_F and D_R above. The dose rate for the mid point will be 2 x D_M.

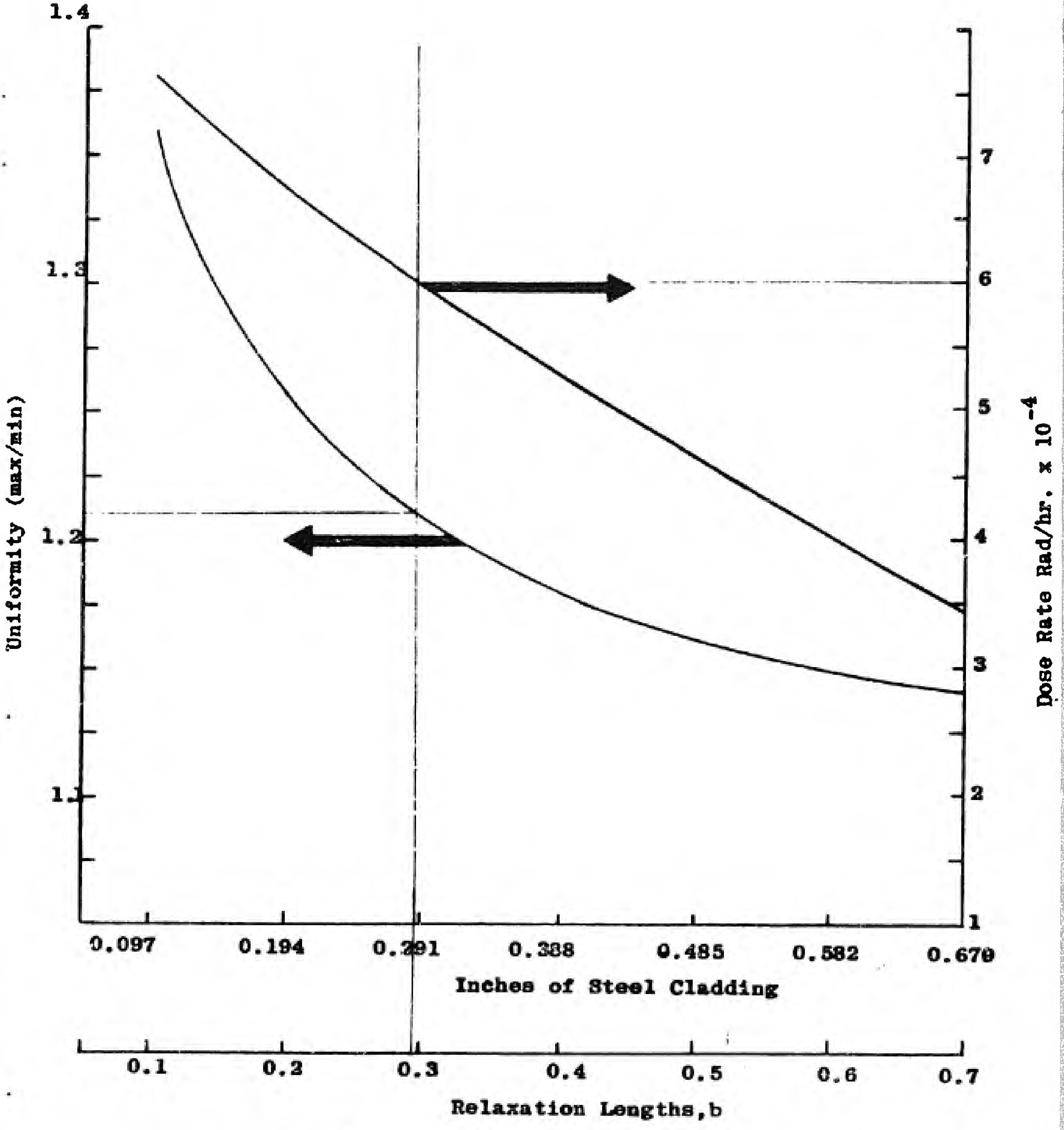
Therefore, dose rate at surface midpoint = 5.06 Mrad/hr

dose rate at midpoint of target = 4.14 Mrad/hr

It follows that the dwell time for a dose of 5 Mrad is 72.5 plus 4 = 76.5 minutes, and that the max.:min. ratio is 1.23.

The source characteristics, derived by these two complementary methods, are tabulated below:

	Graphical Data		Calculated Data
Total Activity		1.1 Megacuries	
Active Height of Rods		42.2 inches	
Overall Height of Array		42.6 inches	
Active Length of Array		56.2 inches	
Overall Length of Array		56.6 inches	
Geometry Factor	0.06	Mrad/hr per curie/cm^2	0.058
Activity Density (in each plaque)		35.9 curies/cm^2	
Dose Rate (Minimum)	4.31	Mrad/hr	4.14
Capacity (in terms of cartons of No. 10 cans each 40 lbs. net)		125 lbs./hr	
Capacity (in terms of 6" x 26" x 38-1/2" space filled with water)		215 lbs./hr	
Uniformity	1.21		1.23
Dwell Time for 5 Mrad (including 4 mins. transit)	73.5	Minutes	76.5



Changes in Dose Rate and Uniformity as a Function of Cladding Thickness for a 57" High, 50" Long Plaque Source with a 2½ in. Air Gap and 6 in. Water Target Thickness

FIGURE II IV (formerly FIG. II 29)

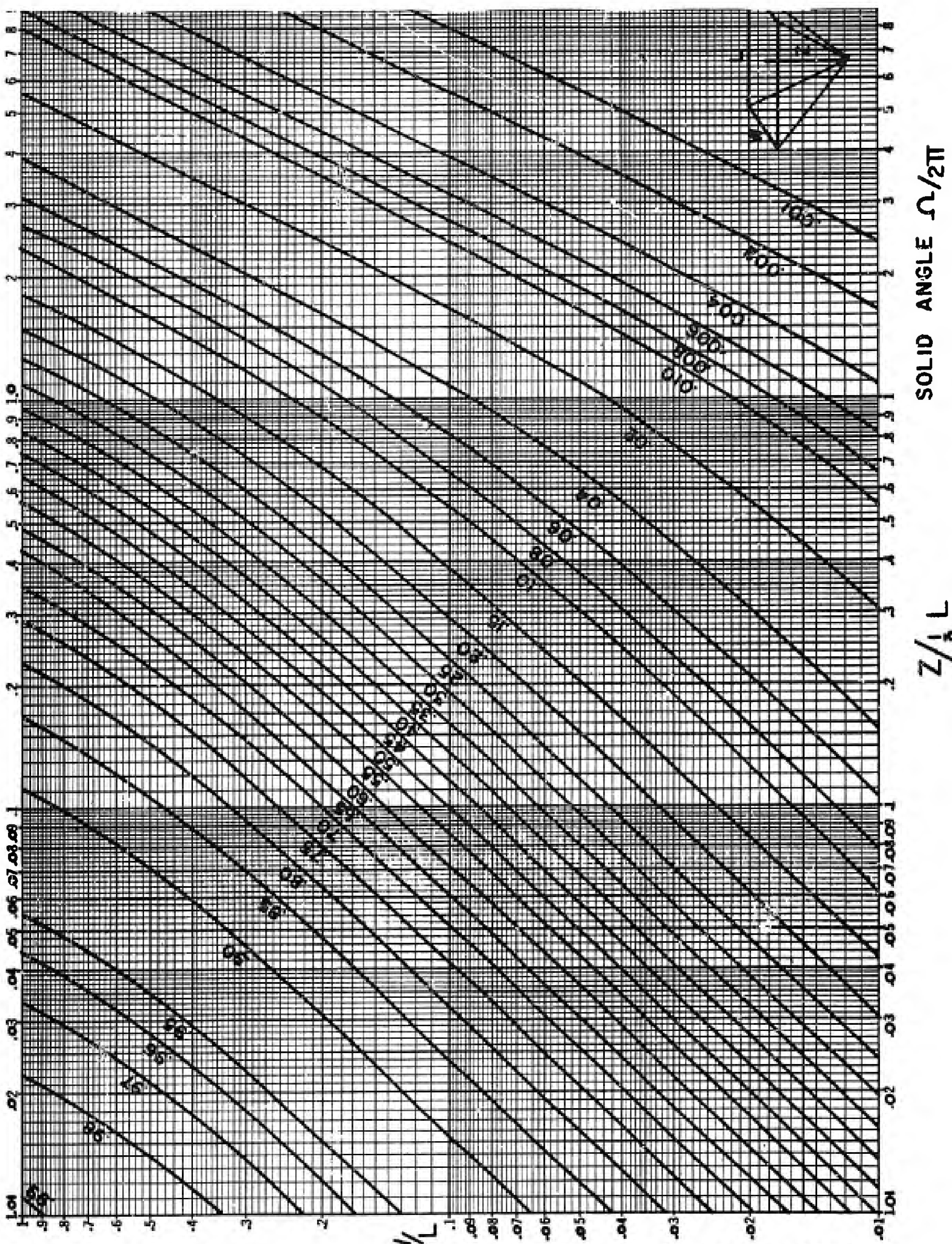


Figure II-5 (previously **Figure II-41**)

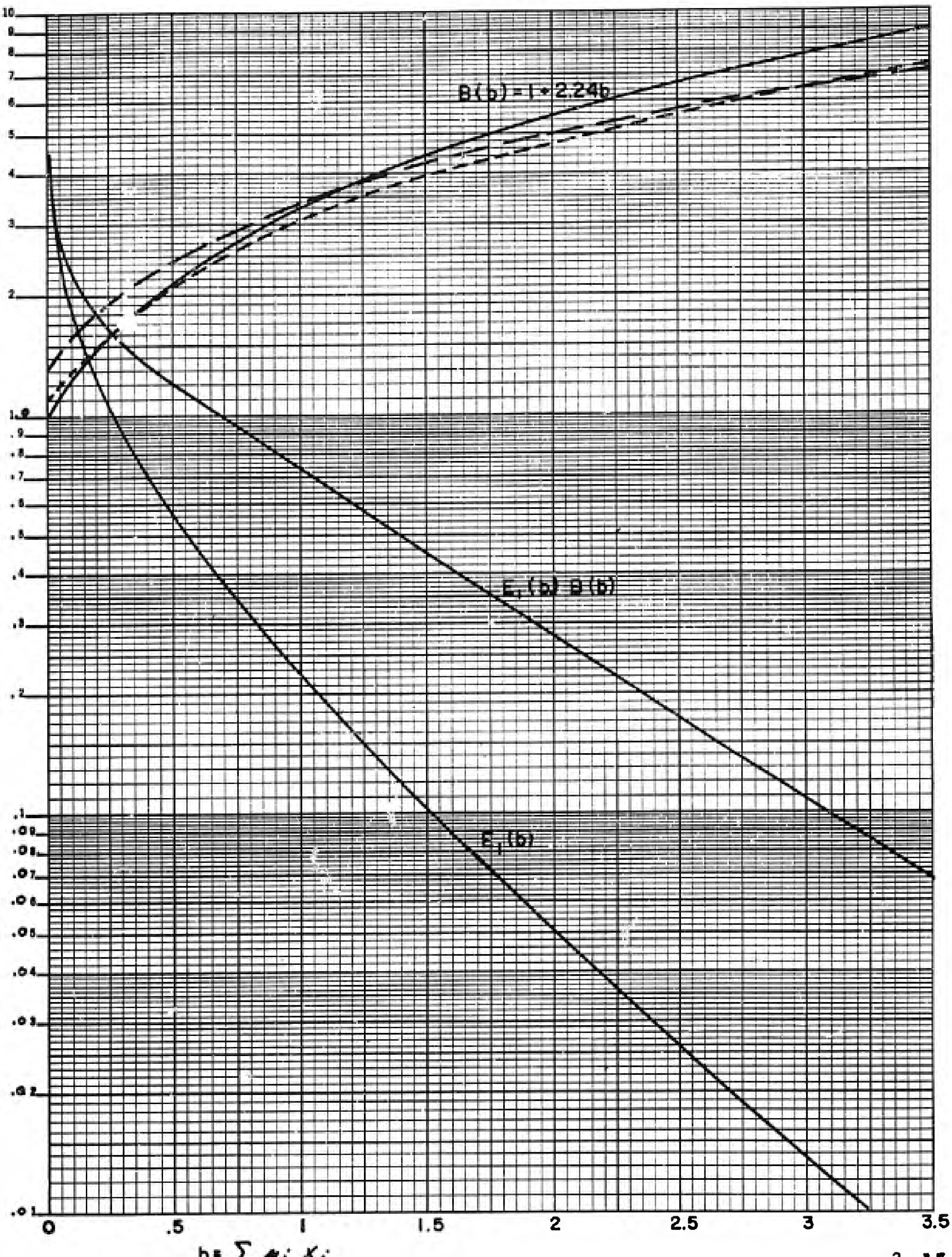


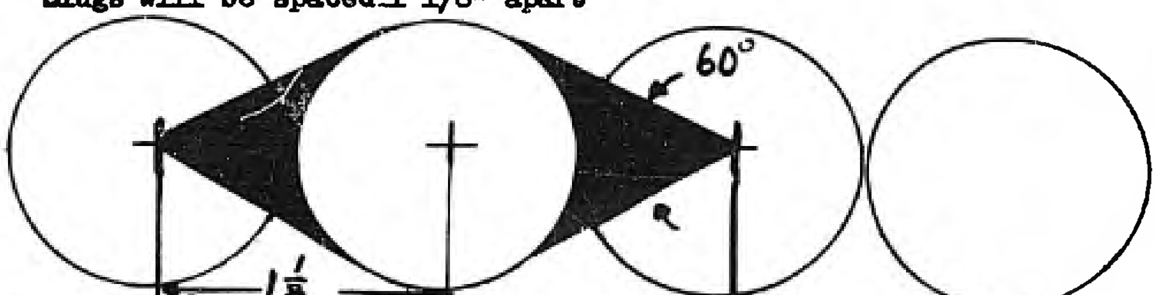
Figure II-6 (previously Figure II-42)

PLAQUE TEMPERATURES

Steady State Temperature of Cobalt Slugs in Air

Case "A": with 10 f/sec. air flow
Case "B": in still air

Assume 3,300 curies/slug maximum
Air temperature 100°F
Slugs will be spaced 1 1/8" apart



Use Cobalt 60 with two γ's per disintegration (1.17 & 1.33 Mev) and one β (0.3 Mev).

The energy released per second is:

Total γ :

$$E_\gamma = 3.3 \times 10^3 \text{ curie} \times 3.7 \times 10^{10} \frac{\text{disintegration}}{\text{curie}} \times$$
$$(1.17 + 1.33) \times 10^6 \text{ ev} \times 1.6 \times 10^{-12} \frac{\text{ergs}}{\text{ev}}$$

$$E_\gamma = 4.93 \times 10^7 \frac{\text{ergs}}{\text{sec}} = \underline{49.0 \text{ watts}}$$

Total β :

$$E_\beta = 3.3 \times 10^3 \text{ curie} \times 3.7 \times 10^{10} \frac{\text{disint.}}{\text{curie}} \times 0.3 \times 10^6 \text{ ev}$$
$$\times 1.6 \times 10^{-12} \frac{\text{ergs}}{\text{ev}}$$

$$E_\beta = 5.8 \times 10^7 \frac{\text{ergs}}{\text{sec}} = 5.8 \text{ watts}$$

Assume 25% self-absorption of γ energy and 100% self-absorption of β energy. Then the self-absorbed energy per slug is

$$q_a = 1/4\ (49) + 5.8 = 18 \text{ watts}$$

The middle slugs will also receive radiation from the adjacent sources over a cylindrical angle of 60° from each side. Assuming that all this incident energy is absorbed the heat generated is:

$$qi = 2 \times \frac{60^\circ}{360^\circ} \times 75\% \text{ of } \gamma \text{ energy}$$

$$qi = 2 \times \frac{60}{360} \times \frac{75}{100} \times 36.6 = 13.5 \text{ watts}$$

and the total energy per slug absorbed is:

$$Q = qa + qi$$

$$Q = 18 + 13.5 = 31.5 \text{ watts/slug}$$

each slug is 10.65 inches long; so that heat generation is

$$q_o = \frac{31.5}{10.65} = 2.96 \text{ watts/inch length}$$

$$q_o = 2.96 \times 3.413 \text{ Btu/hr/inch}$$

$$q_o = 121 \text{ Btu/hr/ft length}$$

Since rods are slender, the end effects can be neglected and the heat transfer can be assumed as taking place only in radial direction.

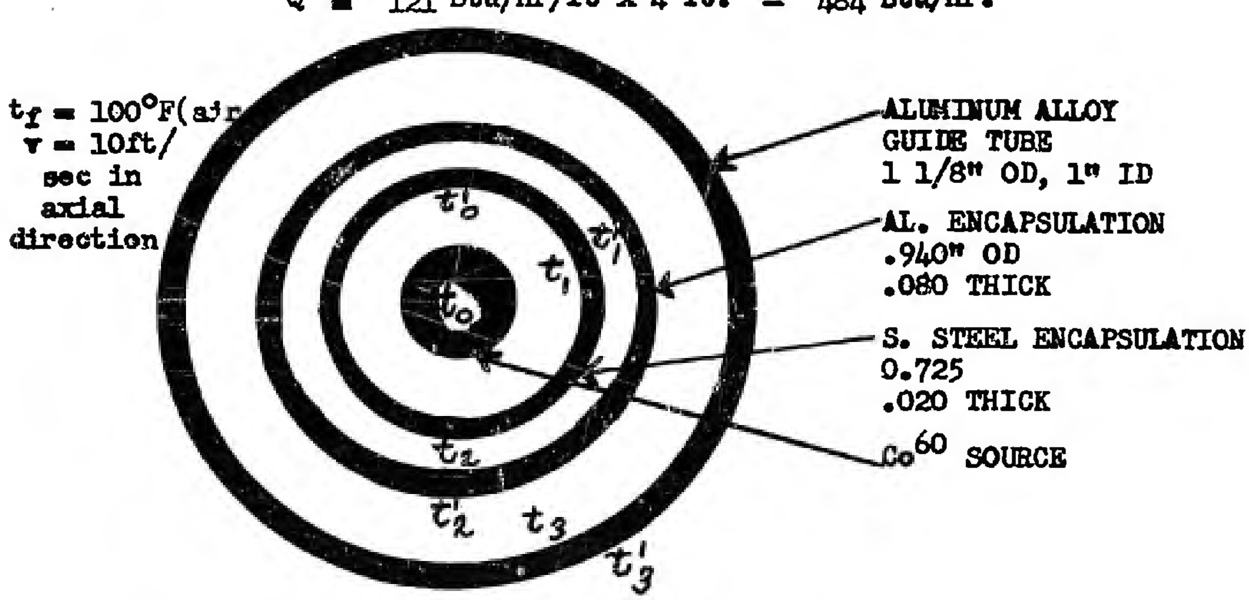
The area over which heat transfer is effected can then be assumed as being a cylinder of infinite length for the purpose of this calcul[illegible].

Since thickness of materials surrounding the cobalt source are very small, the area can be assumed to be a constant for all calculations and equal to unity. (1 sq. ft.)

For 1 sq. ft. of heat transfer area the length of slugs contained is 4 ft. This gives a heat generation of

$$Q = q_o \times 4 \text{ ft.}$$

$$Q = 121 \text{ Btu/hr/ft} \times 4 \text{ ft.} = 484 \text{ Btu/hr.}$$



Heat transfer calculations will be based on:

1. Kent's Mech. Eng's. Handbook and

2. Heating, Ventilating & Air Conditioning Guide, 1958

Assume heat flow with combined conduction and surface effects only (neglect radiation). For the heat flow between the cobalt source and the guide tube the case will approximate case of transmission between flat parallel plates because spaces and thicknesses are small in respect to the radius of curvature.

Assume uniform temperature inside cobalt ^{60} source $t_o = t_o'$

The equations for the heat flow through 1 sq. ft. of wall area are:

$$Q = C_s (t_o' - t_1) = \frac{Kss}{Lss_1} (t_1 - t_1') = C_s' (t_1' - t_2) =$$

$$\frac{Kal}{Lal_2} (t_2 - t_2') = C_s'' (t_2' - t_3) = \frac{Kal}{Lal_3} (t_3 - t_3')$$

$$= h_c (t_3' - t_f)$$

where:

h_c = coefficient of surface transmission in Btu/hr/sq. ft/°F

L = thickness of material in inches

C_s = air space conductance in Btu/hr/sq. ft/°F

K = conductivity in Btu/hr/sq. ft/°F/inch

The overall transmission in Btu/hr/sq. ft/°F is:

$$U = \frac{1}{\frac{1}{C_s} + \frac{Lss}{Kss}1 + \frac{1}{C_s} + \frac{Lal}{Kal} + \frac{1}{C_s}11 + \frac{Lal}{Kal} + \frac{1}{h_c}}$$

The values for C_s are extrapolated from (1) Fig. 4, page 3-60 and are conservative.

$C_s = 14$	for	.01" air gap
$C_s' = 14$	for	.01" air gap
$C_s'' = 5$	for	.01" air gap

$$\frac{Lss_1}{Kss} = \frac{.020"}{350 \text{ Btu/hr/sq. ft/}^{\circ}\text{F/in.}} = 5.7 \times 10^{-5}$$

this is negligible

$$\frac{Lal}{Kal} = \frac{.088"}{1475 \text{ Btu/hr sq. ft/}^{\circ}\text{F/in.}} = 6.0 \times 10^{-5}$$

this is also negligible

$$\frac{Lss_3}{Kss} = \frac{.065"}{1475} = 149 \times 10^{-5}$$

which is also negligible

h_c is calculated from (2) page 93, case 2, for forced convection (condition "A", with air flow of 10 ft/sec.)

$$h_c = 5.4 \times 10^{-4} \ (Tf)^{0.3} \ \frac{G^{0.8}}{D^{0.2}}$$

where: D = diameter $\cong \frac{1}{12}$ ft $\cong$ 0.09 ft.

G = mass flow per unit cross-sec. area

$$= 3600 \times 10 \text{ ft}^3\text{/sec.} \times .07 \frac{\text{lbs}}{\text{ft}^3} = 2520 \frac{\text{lbs}}{\text{hr}}$$

Tf = 120°F (assumed average between air & wall) = 120°F + 460 = 580

$$h_c = 5.4 \times 10^{-4} \ (580)^{0.3} \ \frac{2520^{0.8}}{0.09^{0.2}}$$

$$h_c = \frac{5.4 \times 10^{-4} \times 6.7 \times 560}{.62} = 3.30$$

and overall transmission is:

$$U = \frac{1}{\frac{1}{14} + \frac{1}{14} + \frac{1}{5} + \frac{1}{3.3}} = 1.55 \text{ Btu/hr/sq. ft/}^{\circ}\text{F}$$

and since

$$Q = U (t_o - t_f) = U (\Delta t)$$

$$\Delta t = \frac{Q}{U} = \frac{484}{1.55} = \underline{311^oF}$$

checking the outside temparature of the guide tube we obtain from

$$Q = h_c \; (t_3' - t_f)$$

$$t_3' = \frac{Q}{h_c} + t_f = \frac{484}{3.3} + 100^oF = 247^oF$$

Since the original assumption was $t_3' = 140^oF$ a revised calculation is necessary for h_c.

Assume $t_3' = 200^oF$, then $T_f = \frac{t_3' + t_f}{2} + 460 = 150 + 460 = 610^oF$

$$h_c = 5.4 \times 10^{-4} (610)^{.3} \; \frac{2520^{0.8}}{0.09^{0.2}}$$

$h_c = 3.34$ which is practically the same value obtained previously.

The temperature drop between the cobalt source and the surrounding air (flowing at a rate of 10 f/sec. in axial direction) is

$$\underline{\Delta t = 311^oF}$$

and the temperature of the outside of the guide tube is:

$$t_3' = 247^oF$$

the maximum temperature of the cobalt 60 source is:

$$t_o = tf + \Delta t = \underline{t_o} = 100^oF + 311^oF = \underline{411^oF}$$

Case B

No forced air circulation

$$h_c' = .354 \left(\frac{P}{P_o}\right)^{0.50} \left(\frac{\Delta t}{l}\right)^{0.25}$$ (table 2 P. 94)

$P = P_o =$ atmospheric pressure

$\Delta t = t_3' - t_f$, assume 200^oF

$l = 4$ ft.

$h'_o = .354 \left(\frac{200}{4}\right)^{0.25} = 0.94$ and the overall transmission is

$$U' = \frac{1}{\frac{1}{-} + \frac{1}{14} + \frac{1}{5} + \frac{1}{0.94}} = .71$$

$$\left(\underline{\underline{\Delta t}} = \frac{Q}{U^1} = \frac{484}{.71} = \underline{\underline{680^\circ F}} \right)$$

$$t_o = tf + \Delta t = 100 + 680^\circ F \quad \underline{\underline{(t_o = 780^\circ F)}}$$

Verification of t'_3 : from $Q = h'_c \, (t'_3 - t_f)$

$$t'_3 = \frac{Q}{h'_3} + t_f = \frac{484}{.94} + 100^\circ F = 613^\circ F$$

Revision is needed for values obtained previously.

assume $t'_3 = 500^\circ F$ then $t'_3 - t_f = 500 - 100 = 400^\circ F$

and $h'_3 = .354 \left(\frac{400}{4}\right)^{0.25} = 1.12$

$$U' = \frac{1}{\frac{1}{14} + \frac{1}{14} + \frac{1}{5} + \frac{1}{1.12}} = .81$$

$\underline{\underline{\Delta t}} = \frac{Q}{U'} = \frac{484}{.81} = \underline{\underline{598^\circ F}}$ and $t'_3 = \frac{Q}{h'_c} + tf = \frac{598}{1.12} + 100$

$= \underline{632^\circ F}$

$$\underline{\underline{t_o}} = t_f + \Delta t = 100 + 598 = \underline{\underline{698^\circ F}}$$

But in this case radiation will be an important factor in heat elimination and should be included. The calculations for condition "B" are revised to account for heat losses due to radiation.

The heat loss due to radiation is given by

$$qr = \sigma \, A \, F_A \, F_E \, (T_1^4 - T_2^4) \qquad (2) \text{ P. } 92$$

where $F_A = 1$ (small body in large enclosure)

$F_E = .15$ for oxidized aluminum surface at $500^\circ F$ (1) P. 3-33

$\sigma = 1730 \times 10^{-12}$ Btu/hr/sq. ft./($^\circ$F abs)^4

Assume wall temperature of room $= 70^\circ F = 530^\circ F$ absolute.

Also assume $t_3' = 300^\circ F = 760^\circ F$ absolute; also include factor 2/3 since only 2/3 of the area of the cylinder can radiate to walls.

$$qr = 1730 \times 10^{-12} \times 2/3 \times 1 \times .23\ (760^4 - 530^4)$$

$$qr = 66 \text{ Btu/hr}$$

then the value found on p. 3-21 becomes

$$\Delta t = \frac{Q - qr}{U'} = \frac{484 - 66}{.81} = 508^\circ \text{ and}$$

$$t_3' = \frac{Q - qr}{h'_c} + t_f = \frac{418}{1.12} + 100 = 474^\circ$$

which diverges from assumption ($300^\circ F$)

Revise assumption to:

Wall temp of room $= 100^\circ F = 560^\circ F$ abs.

$t_3' =$ temp of guide tube $= 400^\circ F = 860^\circ F$ abs.

$$qr = 1730 \times 10^{-12} \times 2/3 \times 1 \times .15\ (860^4 - 560^4)$$

$$Qr = 76 \text{ Btu/hr.}$$

and the Δt from Page 21 becomes $\Delta t = \frac{484 - 76}{.81} = 502^\circ F$

$$t_3' = \frac{484 - 76}{1.12} + 100 = 465^\circ F$$

$$t_o = t_f + \Delta t = 100 + 502 = 602^\circ F.$$

SUMMARY

	Temperature	
	Case "A"*	Case "B"**
Cobalt ^{60} Source	411°F	602°F
Guide Tube	247°F	465°F

* Heat elimination by radiation neglected; air cooling 10 ft./sec.

** No circulating air. Radiation losses included.

Air temperature assumed 100°F in both cases.

III. COBALT ENCAPSULATION PROCEDURE

The double encapsulation of cobalt was first considered in reference to the Curtiss-Wright MAGI in which it was proposed to use several encapsulations moving through tubular source guides. In the MAGI device a number of dual canning concepts were considered. They included nickel plating the cobalt, with an outer envelope of stainless steel, a sprayed stainless steel inner casing with a sprayed aluminum outer casing, a stainless steel tubular inner casing with a cast aluminum outer casing. None of these was satisfactory. The sprayed metals were characterized by porosity and the cast metals by porosity and actual casting difficulties.

Impact extruded tubes were investigated with the intention of closing the other end by welding but it was found that the ratio of diameter to extruded length was impractical for long sources of small diameter. Where the ratio of diameter to length was suitable for impact extrusion it was considered acceptable to encapsulate in this way.

Single encapsulation, even with little wear expected, being unacceptable for the FPDI slugs, the previous work on double encapsulation was extended. It was agreed to devise a technique involving a stainless steel inner capsule and an aluminum outer capsule both to be welded gas tight. The requirement by Savannah River Project that radial clearances be kept to a minimum meant that a very close fit had to be obtained mechanically between the cobalt and the stainless steel.

An attempt was made to shrink fit a stainless steel tube onto a cobalt rod. It quickly became apparent that this method was impractical. The cobalt rod was cooled in liquid nitrogen and the tube was heated to approximately 800°F. The tube almost immediately cooled locally on contact with the cobalt and it was thereafter impossible to proceed further with the inserting operation.

In the next attempt a cobalt rod was mechanically pressed into the stainless steel tube and two flat end discs were welded to the tube. The diameter of the discs was the same as the tube O. D. and welding was done around the tube O. D. It was later polished to size. This was considered to be a successful first stage because the contact between cobalt and stainless steel was in the order of .0015" and the weld was sound. The second stage was then assembled by using mechanical pressure to insert the first stage in the aluminum tube. End plates were welded on in the same manner as in the first stage.

A discussion was then held on the completed encapsulation and it was decided to redesign the end components to obviate the risk of including "micropipes" which would be present in the end caps if they were cut from bar stock. It was decided, therefore, to trepan them from sheet material for future test specimens and to investigate the possibility of coining for production items.

New end caps having flanged rims were made by machining them from sheet material, the O.D. being equal to the I. D. of the tube for both 1st and 2nd stage. The cross-sectional areas were kept equal to those of the corresponding tubes. Two 1st stages and two 2nd stages were made and examined for weld quality in the metallurgical laboratory at W. A. D. This examination showed that foreign material had been trapped during the insertion procedure. The stainless steel welds appeared quite sound with approximately 30% depth penetration. The greatest void between stainless steel and cobalt was measured at the radius on the end of the cobalt rod. This measured 0.006" from the radiused corner to the stainless steel. The trapped foreign matter caused a radial clearance of .0025" while typical clearances were in the range of .0005" to .004". Average radial clearance was .0021".

Five complete encapsulations were then made using 10-1/4" long cobalt rods ground to 0.7265" on the O. D.; these were a force fit in the .725" I. D. stainless steel inner tubes. The end caps were trepanned from sheet stainless steel and a flange was incorporated so that welding could be done on the end instead of on the O. D. The O. D. of the end cap was a snug fit in the tube I. D. This construction resulted in a concavity or recess 0.015" deep on the end of the 1st stage. The concavity was to be substantially filled by a boss machined on the end caps of the second stage. The outer tubes were bored from solid aluminum bar of 99.99% purity, tubing of the right I. D. being unobtainable in these quantities, and the first stages were mechanically pressed into them. The second stage end caps were trepanned from sheet aluminum and welding was done on the end face as in the first stage. The five samples were marked X-1 through X-5 and shipped to S.R.O.O.

Several additional samples were made with various degrees of success. The major effort was concentrated on procuring tight fitting envelopes and close fitting end caps.

A new effort was initiated with emphasis directed toward improvement and control of the welding technique. Since the stainless steel walding had been consistently good, the additional effort was concentrated on the aluminum welding. Several design changes were made on the end cap which eventually evolved to a cupshape with an internally chamfered outer flange with a similar external chamfer on the end of the aluminum tube. The chamfered end rim was finally reduced to a 60° included angle toward which the tungsten welding electrode was directed.

The chamfering of the end rim resulted in the following distinctive advantages:

a. It permitted successful welding without the necessity of subsequent machining to remove the surplus metal.

b. The 60° included angle, its peak being directed to the electrode, afforded a deeper weld penetration.

c. The welded 60° section culminated in an elevation of the welded rim lower than the surface of the central boss which therefore will be in contact with the adjacent encapsulation when they are assembled together.

d. This surface was not damaged by the welding.

To improve the welding technique still further a lathe was procured and mounted on a hinged base. With the encapsulation in the chuck, the tailstock could be inclined 45° upward from horizontal to give better control of the flow of molten metal during welding of the aluminum. It was found more advantageous to weld the stainless steel 1st stage in the horizontal position.

A special variable speed drive was attached to the lathe to facilitate the establishing of an optimum speed for both the aluminum and the stainless steel welds. The settings used on the welding equipment and the lathe to produce acceptable welds are given later in this section. Excellent welds were made under these conditions. It was noted that samples with contaminated surfaces would not weld satisfactorily. Scrupulous cleanliness is thus essential at all stages.

It became apparent that although the average clearance between the stainless steel and aluminum jackets was close to the permissible limit, for full assurance it would be necessary to use some positive sizing technique to minimize this gap.

First experiments were with a thermal sizing die. A closely fitting steel die was made, in two half sections bolted together. This could be tightened onto the aluminum encapsulation at room temperature. It was calculated that heating to 400°F would result in a net reduction in I. D. of the aluminum tube of not less than .0015 inches, due to the differential expansion between the aluminum and steel.

Encapsulations were prepared with the aluminum tube of I. D. 0.7658 inches, leaving a gap between it and the steel encapsulation of less than .001 inches. This assembly was bolted into the thermal die heated to 400°F and allowed to cool. Subsequent sectioning of the slug revealed essentially zero gap between steel and aluminum. Other samples were prepared with similar results indicating that thermal sizing would produce the desired result. The next steps in the encapsulation procedure were directed towards a cold sizing technique, and a heavy steel fixture was made through which the second stage encapsulation could be pushed mechanically. This was to be done after welding one end. With close tolerances maintained between steel and aluminum encapsulations, a very tight fit could reliably be made using the die sizing fixture illustrated. This had the advantage of producing a final capsule of the correct O. D. with a very clean smooth finish.

The final procedure to be used for the cobalt encapsulation is now described.

1.0 Description of Cobalt Encapsulation

The cobalt encapsulation is a double encapsulation. It consists of a cobalt rod completely encased in a stainless steel can which is in turn completely encased in an aluminum can. All joints are welded to provide two leak-tight cans surrounding the cobalt.

The encapsulation of the cobalt rod in the stainless steel is designated as the "first stage" encapsulation and the encapsulation of this first stage in the aluminum is designated as the "second stage" encapsulation.

Each stage requires one tube and two end caps of the same alloy. The tubes are to be made from precision drawn tubing as specified. The end caps are to be made from sheet stock to eliminate the possibility of so called "micro-pipes" which can occur in bar stock.

Welding of both stages will be done by a certified welder using the inert gas tungsten arc method. No filler rod is used in the welding operations.

All materials will be cleaned and inspected thoroughly after each series of operations to maintain high quality throughout.

2.0 Cobalt Specifications

2.1 Material

Reactor grade cobalt ^{59} bar casting, ground to size. Batch analyses to be provided by supplier.

2.2 Dimensions and Finish

0.725" $\pm$ .0005" dia. by 10.250" $\pm$ .002" long centerless ground on diameter and flat ground both ends.

Straightness - .005" (camber)

32 microinch finish on diameter.

63 microinch finish on ends.

Reference: Figure 3-4

2.3 A Source of Supply

Deloro Stellite Company, Belleville, Ontario, Canada.

2.4 Quality Control Inspection

The following conditions are acceptable:

a. Centerline porosity resulting from cooling after casting. Maximum diameter 1/32 inch.

b. Minor surface imperfections such as minute sand holes approximately 1/16" diameter by 1/16" deep provided the number of such imperfections does not exceed ten (10) per bar and provided they are not closely grouped.

The following conditions are unacceptable:

a. Deviations from size specifications.

b. Local raised bulges or protuberances resulting from shock contact with other bars during shipment from vendor.

c. Oxidized surface.

d. Cracks visible to the naked eye.

e. Slag inclusions or other material defects visible at surface.

3.0 Stainless Steel Specifications

3.1 Material

18% Cr., 8% Ni., stainless steel type 302 or 304. Same type stainless steel to be used for tubes and caps. Batch analysis to be provided by supplier to show all trace elements above .005% by weight.

3.2 Dimensions and Finish

3.2.1 Tube. Seamless tube redrawn from mill size tube to precision sized tube.

I. D. 0.725" ± .001"

O. D. 0.765" ± .001"

Preliminary cut length 10 3/4"

Straightness .008". (camber)

32 microinch finish inside and outside.

Reference: Figure 3-5.

3.2.2 End Caps. Machined or coined from sheet stock (not acceptable if cut from bar stock).

Reference: Figure 3-6

3.3 A Source of Supply

Peter Frasse Co., Inc., 3911 Wissahickon Ave., Philadelphia 29, Pa., representing Superior Tube Co., Inc.

N. W. Germantown Pike and Cross Keys, Collegeville, Pa.

4.0 Aluminum Specifications

4.1 Material

An aluminum alloy known as type 1245 will be used. The analysis of this alloy is as follows:

Element	Content Weight Percent
Aluminum	99.45 to 99.60
Copper	0.04 Max.
Iron plus Silicon	0.55 Max.
Iron	2 x Si Max.
Boron	0.001 Max.
Cadmium	0.003 Max.
Manganese	0.03 Max.
Magnesium	0.01 Max.
Zinc	0.03 Max.
Titanium	0.03 Max.
Lithium	0.008 Max.
Tin	0.01 Max.
Lead	0.01 Max.
Bismuth	0.01 Max.
Chromium	0.03 Max.
Nickel	0.01 Max.
Cobalt	0.001 Max.

Batch analysis to be provided by supplier.

4.2 Dimensions and Finish

4.2.1 Tube. Seamless tube resized and redrawn from mill tube to precision tube.

I. D. 0.767" ± .001".

O. D. 0.943" ± .002".

Straightness - .020"/piece

Preliminary cut length 11"

32 Microinch finish inside and outside.

Reference: Figure 3-7

4.2.2 End Caps. Machined from sheet stock or coined from sheet stock (not acceptable if cut from bar stock).

Reference: Figure 3-8

4.3 Vendor

Aluminum Company of America
744 Broad Street, Newark, N. J.

(Alternate redraw mill, Precision Tube Company, North Wales, Pa.)

5.0 First Stage Encapsulation - Stainless Steel

5.1 Cleaning and Quality Control Inspection

5.1.1 Cobalt

a. Clean ultrasonically in a detergent solution.
b. Rinse immediately in distilled water.
c. Air dry, visually inspect for dryness and individually wrap in protective wrapper.
d. Handle with gloves thereafter.

5.1.2 Stainless Steel Parts

a. Clean tubes ultrasonically in detergent solution.
b. Rinse immediately internally and externally, in distilled water.
c. Air dry, visually inspect for dryness and individually wrap in protective wrapper.
d. Clean end caps ultrasonically and proceed in accordance with b. and c. above.
e. Handle parts with gloves thereafter.

5.2 Insertion of Cobalt into Stainless Steel Tube

This operation is to be performed under semi-selective assembly methods to maintain minimum gap between cobalt and stainless steel.

5.2.1 Using gloves, insert cobalt into stainless steel tube.

5.2.2 Press cobalt rod into tube using clean, grease-free equipment without the aid of a lubricant or other foreign material.

5.2.3 Using gloves, insert end caps and machine tube ends flush with end cap projection.

5.2.4 Inspect for cleanliness and quality control.

5.2.5 Wrap in protective wrapper until welding operation is carried out.

5.3 Welding

Weld stainless steel end caps to tube in semi-automatic welding set up in accordance with the following:

Welding polarity	-	DCSP
Welding current	-	60-70 amp.
Position	-	Horizontal
Positioner speed	-	1/3 rpm
Electrode	-	1/16" dia. thoriated tungsten (Pointed)
Torch	-	#9 pencil
Cup size	-	#6
Argon Flow	-	15 cfh
Arc length	-	1/16
No. passes	-	1 1/4

5.4 Clean and quality control inspect welds.

5.5 Leak test.

5.6 Ultrasonically clean, rinse, air dry and wrap in protective wrapper.

Reference: Figure 3-9

6.0 Second Stage Encapsulation - Aluminum

6.1 Cleaning and Quality Control Inspection

6.1.1 Aluminum Parts

a. Clean tubes ultrasonically in deoxidising solution.
b. Rinse immediately in distilled water and alcohol.
c. Air dry, visually inspect for dryness and individually wrap in protective wrapper.
d. Clean end caps ultrasonically in deoxidizing solution and proceed in accordance with b. and c. above.
e. Handle parts only with gloves and clean tools thereafter.

6.2 Insertion of First Stage into Aluminum

6.2.1 Using gloves, insert First Stage into aluminum tube.

6.2.2 Using gloves, insert end caps into aluminum tube with one end cap flush with tube end.

6.2.3 Inspect for cleanliness and wrap in protective wrapper if satisfactorily clean.

6.3 First Aluminum Weld

The second stage welding operation will be carried out in two steps. The first step will be the welding of the end cap positioned flush with the tube. This operation will be performed in accordance with the semi-automatic set-up outlined in Section 6.3.1.

6.3.1 Welding Parameters

The aluminum welding operations will be carried under the following:

Welding polarity	-	AC High Frequency
Welding current	-	70-80 Amp.
Position	-	45°
Positioner speed	-	2 rpm
Electrode	-	1/16" dia. thoriated tungsten (Ball pointed)
Torch	-	#9 pencil
Cup Size	-	#6
Argon Flow	-	15 CFH
Arc Length	-	1/16.
No. passes	-	1-1/4

Reference: Figure 3-10

6.4 Clean and quality control check weld.

6.5 Perform die sizing operations as follows: (see Figure 3-11)

6.5.1 Remove excess metal (if any) from O. D. of weld.

6.5.1A. If any metal removed, repeat Q. C. inspection.

6.5.2 Apply "Door-Ease" around welded end to facilitate passage through sizing die.

6.5.3 Insert welded end in sizing die guide and check for correct vertical insertion.

6.5.4 Using clean tools, insert second end cap.

6.5.5 Coin end cap down snug and continue pressing until assembly has passed completely through sizing die. Prevent assembly from falling as it emerges from die.

6.6 Trim and chamfer unwelded tube end to make tube end flush with end cap.

6.7 Inspect and wrap in protective wrapper.

6.8 Perform second end cap weld in accordance with Section 6.3.1.

6.9 Clean and inspect welds.

6.10 Leak test.

6.11 Engrave 3/16" high by .020" - .025" deep symbols on each end cap.

Reference: Figure 3-12

6.12 Ultrasonically clean in detergent solution.

6.13 Inspect for final packaging.

6.14 Individually package in protective wrapper.

7.0 Packaging for Shipment to Reactor

All encapsulations are to be carefully handled to prevent dropping or damage to the aluminum. Any piece that is dropped or damaged in any way is to be reinspected before packaging.

7.1 Pack wrapped encapsulations in 1 1/8 I. D. by 1/8" wall hard paper tube with tissue filler. Fill ends of tube with tissue and close with adhesive tape.

7.2 Pack in cartons of twenty-five with Kempoc cushions at end of paper tubes.

7.3 List identification symbols on cartons.

7.4 Pack cartons in shipping boxes.

Activation of Aluminum Cladding

With the decision to use a double pre-activation encapsulation technique, it was necessary to show that the impurities present in the aluminum were in such small quantities that they would not present any contamination hazard in using the facility.

The common alloy metals of aluminum are:

Silicon
Iron
Copper
Manganese
Magnesium
Chromium
Nickel
Zinc
Titanium

For the operation of the FPDI we are interested only in activity which is significant a considerable period of time after activation in the reactor. Let us consider this period to be 60 days.

Then any isotope with a half life of shorter than 1 day will decay by a factor of greater than 10^{18} in 60 days and may be ignored in consideration of possible contaminants.

The radioisotopes of the alloy elements which have half-lives longer than 1 day and which may be produced by reactor activation are:

Fe^{55}, Fe^{59}, Cr^{51}, Ni^{59}, Ni^{63}, Zn^{65}

The relative importance of these isotopes will now be considered by estimating the activity produced assuming a 90 day activation at a flux of 10^{14} n/cm²/sec.

The activity present in the alloy from a 1% concentration of target element after a 90 day activation and 60 day decay period is:

$$S = \frac{0.6\, I \sigma a}{3.7 \times 10^{10} A} \left(1 - e^{-0.695/T}\right) e^{-\frac{0.69t}{T}} \qquad 2$$

$$= \frac{1.62 \times 10^{3} \sigma a}{A} \left(1 - e^{\frac{-62.1}{T \text{ days}}}\right) e^{-\frac{41.4}{T \text{ days}}}$$

Cont'd.

where a = Fractional abundance
A = Atomic wt. σ = cross section in barns
T = half-life

The results are tabulated below in Table I.

Radio-Isotope	σ	T (days)	A	a (assuming alloy with 1% Target Element	Sg (curies/gm concentration of activity in alloy
Fe^{55}	2.2	1.07×10^3	54	$\frac{1}{100} \times \frac{1}{16}$	2.5×10^{-3}
Fe^{59}	1.0	45	58	$\frac{1}{100} \times \frac{1}{300}$	7×10^{-4}
Cr^{51}	13.5	2718	50	$\frac{1}{100} \times \frac{1}{25}$	3.5×10^{-2}
Ni^{59}	4.3	2.9×10^7	58	$\frac{1}{100} \times \frac{2}{3}$	4×10^{-6}
Ni^{63}	21	4.5×10^4	62	$\frac{1}{100} \times \frac{1}{27}$	3×10^{-4}
Zn^{65}	0.44	245	64	$\frac{1}{100} \times \frac{1}{2}$	1×10^{-2}

The actual concentrations in the pool water of each radioisotope which may be present will now be deduced and from this maximum percentages of the alloy elements will be established for the FPDII case.

Let us assume a rate of corrosion of the aluminum of 0.010" per year which is a very high value for aluminum in deionized water.

The rate of addition of activity to the water is given by:

$$\frac{d\,Si}{d\,t} = MS_g k\, e^{-0.69 t/T}$$

where M is the No. of gms corroded/sec.

S_g is the activity per gm of aluminum for a 1% composition of the element in the alloy.

k is the fraction of 1% of the element to be allowed in the alloy.

$$M = \frac{0.025 \times 217 \times \text{area of 96 rods used in FPDI}}{\text{No. seconds in one year}} = \frac{0.025 \times 2.7 \times 7.6 \times 10^4}{3.15 \times 10^7}$$

$$= 1.65 \times 10^{-4} \text{ gms/sec.}$$

$$\frac{d\,Si}{dt} = 1.65 \times 10^{-4}\, S_g k\, e^{-0.69t/T}$$

The rate of removal of activity from the water (by the deionizer unit) is given by:

$$\frac{d\,So}{dt} = f\,\frac{S}{C}$$

where f = flow rate thru the deionizer
= 5 G.P.M. (minimum)

S = total activity in the tank (curies)

C = capacity of the tank = 25,000 gal.

$$\frac{d\,So}{dt} = \frac{5}{60}\,\frac{S}{25{,}000} = 3.3 \times 10^{-6} S$$

The rate of change of activity in the water is:

$$\frac{d\,S}{d\,t} = \frac{d\,Si}{d\,t} - \frac{dSo}{dt}$$

$$= 1.65 \times 10^{-4}\, S_g k\, e^{-0.69t/T} - 3.3 \times 10^{-6} S$$

This is an equation of the form

$$\frac{dS}{dt} = A e^{-dt} - BS$$

and its solution is:

$$S = C\,(1 - e^{-\beta t})\, e^{-\alpha t}$$

where $C = \frac{A}{B-\alpha}$

and $\beta = B-\alpha$

The time, t max., at which the concentration becomes a max., may be established by:

$$\left.\frac{dS}{dt}\right|_{t = t\ max} = 0$$

$$-\alpha C (1 - e^{-\beta tm}) e^{-\alpha t\ max} + \beta C e^{-(\alpha+\beta) t\ max} = 0$$

$$(\alpha+\beta)\, e^{-(\alpha+\beta)\, t\ max} = \alpha$$

or $$\frac{\alpha+\beta}{\alpha} = e^{B\ t\ max}$$

$$t\ max = \frac{1}{B}\ \mathrm{Ln}\ \frac{(\alpha+\beta)}{\beta} = \frac{1}{B}\ \mathrm{Ln}\ \frac{B}{(\alpha)}$$

The resulting values of S max. are given in Table II.

The actual maximum concentrations are given by:

$$Sc_{max} = \frac{S\ max}{Cap} = \frac{S\ max}{10^8}\ \text{curies/cm}^3 = \frac{S\ max}{10^2}\ \mu\text{curies/cm}^3$$

TABLE II

Element	S_g	T(Secs)	k	A	B	α	β	t max (secs)	C	S max (curies)
Fe^{55}	$2.5x10^{-3}$	$9.2x10^{7}$	1	$4.1x10^{-7}$	$3.3x10^{-6}$	$8x10^{-9}$	$3.3x10^{-6}$	$1.8x10^{6}$	0.12	0.115
Fe^{59}	$7x10^{-4}$	$3.9x10^{6}$	1	$1.15x10^{-7}$	"	$1.77x10^{-7}$	$3.12x10^{-6}$	$9.1x10^{5}$	0.037	0.13
Fe^{59}	$7x10^{-4}$	$3.9x10^{6}$	0.1	$1.15x10^{-8}$	"	$1.77x10^{-7}$	$3.12x10^{-6}$	$9.1x10^{5}$	0.0037	0.003
Fe^{59}			0.01	$1.15x10^{-9}$	"				$3.7x10^{-4}$	3.10^{-4}
Cr^{51}	$3.5x10^{-2}$	$2.4x10^{6}$	1.0	$5.8x10^{-6}$	"	$2.83x10^{-7}$	$3.0x10^{-6}$	$8.1x10^{5}$	1.9	1.37
Cr^{51}	"	"	0.1	$5.8x10^{-7}$	"	"	"	"	0.19	0.137
Cr^{51}	"	"	0.1	$5.8x10^{-8}$	"	"	"	"	0.019	0.0137
Ni^{59}	$4x10^{-6}$	$2.5x10^{12}$	1.0	$6.6x10^{-10}$	"	$7.8x10^{-13}$	$3.3x10^{-6}$	$4.9x10^{6}$	$2x10^{-4}$	$2x10^{-4}$
Ni^{59}	"	"	0.1	$6.6x10^{-11}$	"	"	"	"	$2x10^{-5}$	$2x10^{-5}$
Ni^{63}	$3x10^{-4}$	$3.9x10^{9}$	1.0	$5x10^{-8}$	"	$1.75x10^{-10}$	$3.3x10^{-6}$	$3x10^{6}$	$1.5x10^{-2}$	$1.5x10^{-2}$
Zn^{65}	10^{-2}	$2.1x10^{7}$	1.0	$1.65x10^{-6}$	"	$3.3x10^{-8}$	$3.3x10^{-6}$	$1.4x10^{6}$	0.5	0.46
Zn^{65}	"	"	0.1	$1.65x10^{-7}$	"	"	"	"	0.05	0.046
Zn^{65}	"	"	0.01	$1.65x10^{-8}$	"	"	"	"	0.005	0.0046

It is conceivable that at sometime it might be desirable to empty the pool water into a sewage drain. Under these conditions it is required that the maximum disposable quantity per day of any activity may not exceed prescribed values. Consider the case of the pool being emptied six months after start-up over a period of 5 days through the deionizer which reduces the activity by at least a factor of 10^{-2}. The total activity 180 days after start-up for each radioisotope is compared with the maximum disposable quantity in 5 days in Table III. In each case it is assumed again that 1% of the alloying element is present.

TABLE III

Element	C	β_t	α_t	S discharge μcuries	S disposable in 5 days, μcuries
Fe^{55}	0.12	51.4	0.125	10^3	2.5×10^3
Fe^{59}	0.037	50	2.74	24	50
Cr^{51}	1.9	50	4.5	210	2.5×10^3
Ni^{59}	2×10^{-4}	50	4.5×10^{-6}	2.0	50
Zn^{65}	0.5	50	0.51	3×10^3	5×10^2

Hence the only case in which regulations would be violated by such disposal is the discharge of the water if the aluminum contained 1% zinc.

Consequently, the specifications on the percent composition of the alloy metals in the aluminum may be laid down according to Table IV.

TABLE IV

Element	Maximum permissible % composition
Si	no restriction
Fe	1.0
Cu	no restriction
Mn	no restriction
Mg	no restriction
Cr	1.0
Ni	1.0
Zn	0.1
Ti	no restriction

It will be seen that the alloying and impurity elements present in 1245 aluminum are in all cases below these limits.

In practice it is expected that the actual concentrations of contaminants will be much below the figures calculated here, owing to the very strict assumptions made. For example, corrosion of aluminum fuel elements in deionized water at pH 7.0 and with less than one part per million chloride is found to be very slight, making a corrosion rate of 10 mils per year pessimistic by a factor of 5-10.

In the event that disposal of liquid radioactive wastes should become necessary, such disposal will be in full compliance with Title 10, Part 20 of the Code of Federal Regulations. The liquid waste will be monitored by the Health Physicist prior to disposal to assure that radioactive concentrations are within permissible limits. Waste products containing concentrations in excess of allowable disposable doses will be recycled through the cleanup system and resampled until it is within disposal limits.

IV. Source Handling System

General

Plaque configurations and handling have been determined as a function of the source parameters and the irradiation requirements, as well as the size and shape of the packages contemplated for irradiation. As described in other sections of this report, the source elements may be arranged in three basic patterns.

The three basic plaque configurations are single plate, double plate and cylindrical, each shape permitting a distinctly different type of irradiation exposure, such as double-pass, single-pass and stationary, ultra-high intensity. See Figure 3-13.

All plaques are made up of thin sealed tubes into which the radioactive elements ("slugs") are placed. Source replenishment and variation of plaque intensity distribution may be made conveniently by adding more source tubes, and by properly arranging the slugs inside the tubes, and the tubes within the plaques.

The tubes are supported on baseplates - a different one for each individual plaque form - which, in turn, are bolted to a subframe mounted on an elevator platform. The plaque types outlined earlier are obtained by installing the proper base-plate on a subframe, then sliding the source tubes over the arbors provided in the baseplate ("jigplate").

The subframe is fastened to the main platform frame from below. It may be pulled free of its support through an extractor linkage which is normally turned by hand from inside the cell, but in case of emergency may be operated from the outside of the cell by means of a special, tubular key. This tool is inserted through the ceiling of the cell using close-fitting sleeves embedded in the concrete. (These sleeves are normally closed with concrete filled steel tube plugs.) The key is thereby guided and engages the actuating shaft of the extractor linkage after being extended to floor level.

The safety feature above described enables the subframe and the radioactive plaque with it - to be lowered to the bottom of the pool whenever the main platform frame should be prevented from descending, either as a result of a malfunction of the elevator drive system, or because of a major obstruction in its path. Four eye brackets are welded to the side members of the subframe. They permit cable slings to be attached through the access ports in the cell roof prior to disconnecting the subframe. The frame may then be lowered to the bottom of the pool.

V. Source Handling System - General (Continued)

All work on the plaques, such as loading, unloading, or rearranging of source elements is performed by trained personnel working from a moveable bridge over the pool. Special tools have been developed to permit remote handling of radioactive slugs and source tubes from the safety of the cell floor level.

Special attention has been given to obtaining a maximum of compactness in the plaque design. As will be seen from the individual drawings, when the source is raised, the source platform remains below water level, with the plaque as the only part protruding from the pool, thus permitting the smallest possible clearance between irradiation specimen and the active portion of the plaque.

The source elements, or slugs, will be delivered to the site in special, lead-shielded shipping caskets. After the cleaning process these containers are lowered to the bottom of a separate 24' deep cask pool outside the cell. There the slugs are discharged from the shipping container and, one at a time, are placed inside the loading tube, and allowed to slide down the tube by gravity action into the cell pool.

The slug is received inside the cell pool in a swivel tube socket which, acting as a dash-pot, slows down the fast moving slug, bringing it to a gentle stop. The socket then tilts and brings the slug, which protrudes from it several inches, to a vertical position.

As an alternative, a small wheeled box fitting inside the loading tube may be used to carry one or more source slugs down the loading tube. It has a cable attachment so that it can be withdrawn to the cask pool for the next batch. This method would be advantageous if non-standard items were to be moved in and out of the pool.

V. Source Handling System - General (continued)

In addition to the storage racks for slugs, a rack is provided for storing source tubes. This is arranged along one side of the bottom of the pool, and will accept loaded as well as empty source tubes.

Source tubes are handled by means of a simple long-handled tool which permits locking and unlocking of the tubes in the storage rack and source array jig plates, as well as transferring them from one location to the other.

A conceptual design of the source handling mechanism is shown in Figure 3-14.

Design and Operation

Plaque Frame and Source Elements

The source platform consists of a main frame which is suspended at four points from four individual, stainless steel wire rope cables. Its movement is guided along four tracks attached to the pool liner by wheels mounted on the platform by means of hinged brackets.

The jig plates carrying the source arrays are bolted to a subframe which is suspended from the main frame in a manner permitting it to be unlocked from the main frame and lowered independently.

As shown in Figure 3-15 the rectangular main frame consists of two side members parallel to the long axis of the pool, with cross members connecting the ends. The cross members are arranged below the side members, and substantial triangular gusset plates suitably reinforced, are sandwiched between them. Each gusset plate serves as a mount for the angle bracket weldments which, in turn, support the hinged guide wheels.

Two brackets on the underside of each frame side member support and firmly position the separate plaque carrier frame. A third cross-member is welded between the side members. It provides a mount for the linkage and cam system which enables the subframe to be pulled off the supporting brackets by rotating either of the two fulcrum shafts. The mechanisms involved in this are described separately.

Provision is made on each end member to mount two cable anchoring brackets, with a wide range of vertical adjustment. This feature, combined with the considerable adjustability inherent in the cable end fitting used, affords ample scope for the initial levelling of the platform, as well as any subsequent corrections which may become necessary as the four suspension cables stretch in operation.

Plaque Frame and Source Elements

Each bracket, shown detailed in Figure 3-16, is fabricated from standard aluminum structural angle. Its two elongated holes, together with the two sets of three tapped holes in the frame, permit a total vertical adjustment of 1-7/8 inch. A ½ inch socket head capscrew is provided to perform the actual adjustment. Two capscrews are then tightened, and clamp the bracket firmly to the platform frame.

Figure 3-17 illustrates the features of the bracket described above. As will be seen from this drawing, the bracket design permits also lateral adjustment by providing three holes side-by-side for the cable fitting. In combination with the axial adjustment of the drum of ¼ inch in either direction, this feature makes it possible to assure satisfactory alignment of each suspension cable. This is of importance when the platform is raised to the "up" position and the cable brackets are close to the wind-up drum.

The main platform frame is fitted with two sets of stop brackets mounted on the vertical gusset plates reinforcing the corners of the frame. As shown in Figure 3-18, the design of these brackets provides for two stop pads for each bracket. One stop pad, used in normal operation of the facility, is on top of the frame side members. The second stop pad, made from 2½ x 2½ inch stainless steel structural angle, is welded to the 3½ inch wide bracket plate. It is for use when the platform is to be raised to its highest possible position, for maintenance or other purposes. This, in contrast to the normal operating position, is above the water level. The complete weldments are bolted to the frame, one at each corner.

The stop brackets intended for arresting the platform in its lower position are sections of rolled aluminum angle reinforced by web plates. These brackets are welded to the gusset plates at each corner of the main frame. As shown in Figure 3-19, stainless steel wear pads are bolted to the underside of the bracket. Shims are used to permit accurate and convenient alignment of the four stops. This assures that the descending frame will make contact with all four stops simultaneously.

Source Platform Subframe

As shown in Figure 3-20, the subframe is a rectangular structure made up of two side members and two end members butt-welded together. The members are four-inch aluminum structural channels as listed on the drawing. They are arranged with the flanges facing inward so as to eliminate any possibility of their catching or hanging up on the flanges of the main frame, should the subframe ever have to be lowered separately.

Source Platform Subframe (continued)

Four angle brackets are welded to the side members of the subframe. A large hole in each vertical leg permits cable hooks to be secured to the subframe in the case of an emergency situation requiring that it be lowered separately from the main frame.

Two struts run across the frame and protrude beyond its side members. They are structural channels, oriented to face the same way, and welded from below to the gusset plates reinforcing each corner. The weldment is further strengthened by vertical, triangular gusset plates welded to the vertical webs of subframe side members and the cross struts. The struts are of sufficient length to protrude slightly beyond the side members of the main frame to the underside of which they are secured.

As shown in Figure 3-21, stainless steel wear pads are screwed to the top of the protruding strut ends. Dowel pins are inserted in holes located and drilled at the extreme end of these pads to provide lateral alignment of subframe and platform main frame. The wear pads protrude beyond the webs of the strut channels to form 5/8 inch deep lips which are supported on ledges formed by bracket assemblies bolted to the underside of the lower flange of the main frame side members. The design of these brackets appears clearly in Figure 3-21. They are mounted on the main frame, then adjusted using the completed subframe as a template. Shims are used as indicated to provide easy slip fit of the subframe wear plates in the bracket recesses. The entire bracket assembly is then shifted lengthwise on the side members until all wear plate mounting lips engage the recesses to a depth of 3/8 inch. This engagement should be the same for all four brackets. The brackets are then locked in place by means of dowel pins.

A flat spring is provided at two suspension points. Bolted to the web of the subframe cross-struts, the springs bear against the vertical legs of the main frame brackets. A capscrew passing through the spring is so adjusted in the subframe strut that it will permit the spring to expand ¼ inch. The spring forces coming into play are about 200 lbs. for the fully deflected spring, and 100 lbs. when expanded to the stop. Hence, a total force of 400 lbs. will be exerted by the two springs, tending to push the subframe away from its supporting points, when the frame is in place. This force will be reduced to 200 lbs. - and then transferred to the stop screws after the frame has moved away ¼ inch.

Subframe Release System

As shown in Figure 3-22 a lockplate is bolted to each of the two horizontal corner gusset plates at one end of the subframe. Each lockplate protruding 3 inches beyond the subframe end member, has a milled slot. The slot is engaged by a pin extending downward from a bell crank. Each of the two cranks, Figure 3-23, has a welded-on hub, bored out for a 1 inch diameter shaft. The shaft is locked to the crank hub by means of a Woodruff key and a large set screw. A lock pin, spring or cotter, safeguards the crank from slipping off the shaft should the set screw become loose.

The shafts are machined from square bar stock with the ends left square to form heads. The shanks are supported in sturdy aluminum blocks, bored out for an easy running fit and bolted to the web of the cross member which is welded into the main frame as previously described.

The two cranks are connected by a tie rod having thread ends. Threaded rod ends permit adjustment of the effective tie rod length and, hence crank alignment. This has to be done with regard to the angular position of the extractor pin. It is desirable that the pins of the two bell cranks bear uniformly against the thrust side of the lock plate slots, and that, in operation, they reach their apex simultaneously. Both requirements may be met by shimming one of the two shaft bearing blocks against the frame member, and/or correcting the tie rod length for proper angular alignment of the cranks.

After adjusting the linkage in that manner, the subframe should be made to engage its support by 3/8 inch as previously explained. The two extractor pins should then be in a position approximately 10 degrees beyond their apex, as indicated on the drawing. The thrust from the two flat ejector springs will then tend to force the pins out (to the left on drawing tending to rotate the bell cranks in a counter clockwise direction). A stop screw on each crank is then adjusted to make firm contact with the shaft mounting block, and tightened securely. After that a hole is drilled into each shaft, using holes provided in the supporting blocks as pilots. They are then reamed, and receive a thin aluminum pin. In that manner, unintentional loosening of the subframe system is prevented, without materially increasing the effort required for intentional unlocking. The main safeguard against accidental uncoupling of the subframe is, however, the overcenter effect of the two flat ejector springs.

As previously stated, the subframe extractor system is intended for use in emergencies only. At that time, the long stemmed key lowered through the properly located sleeve in the ceiling of the cell is engaged in the square head of the bell crank shaft concerned.

Subframe Release System (continued)

When turning the shaft in a clockwise direction, the safety lock pins are sheared off, while the extractor pins at first force the subframe deeper into engagement with the supporting brackets. The ejector springs are thereby further tensioned, causing the turning effort to increase. This overcenter, self-locking effect presents an added safety feature assuring firm clamping of subframe to main frame.

The spring action is reversed as soon as the crank pins move beyond their apex. From that point on the spring force tends to act in the direction of unlocking, thus reducing the turning effort of the key progressively. The subframe now moves away from its rest position, pushed by the expanding springs and pulled by the extractor pins. As explained previously, the springs are arrested by stop screws after extending to a pre-determined point at which the subframe supporting tabs still engage their rest pads by 1/8 inch. At that point, therefore, the springs cease to assit the extraction effort; the extractor pins, actuated via the linkage system through the cell roof, are now alone in pulling the subframe the remaining 1/8 inch to the point of separation from the main frame. This assures a controlled separation of the sub and main frames.

Platform Travel End Stops

Upper Level Stops

Four stops are provided, one for each corner of the main platform, as shown in Figure 3-18. They engage stainless steel stop pads, described earlier, bolted to mounting brackets which are welded to the frame. The stops are designed to permit controlled arresting of the platform at two different levels; one level for normal operation of the facility, and the highest level mechanically possible.

The first-mentioned level is so established that the radioactive plaque is the only component of the platform complex to break through the water level. This feature will assure complete safety against the remote possibility of the platform becoming icebound should the pool water ever freeze over in the case of a prolonged period of low temperature operation of the facility. The radioactive elements of the plaque generate enough heat to prevent the source tubes themselves from freezing in at the water line.

The higher level, now, is only used whenever service or maintenance operations on the platform are to be performed, such as adjusting one or several hoisting cables, or if the plaque configuration is to be changed, requiring a change of jig plates. For convenience

Upper Level Stops (continued)

and safety, the platform is arrested at that level by the same method and system employed to stop it at the normal level, simply by permitting a second set of stop pads, mounted lower on the platform frame, to strike the stops. This is achieved by unlocking each stop from its mount and rotating it as shown in Figure 3-18. It is thus brought into a position where it cannot contact the normal level stop pads on top of the frame side members, but the high level pads protruding laterally from the frame side members 10 inches below are effective.

The design of the two-level stops is apparent from the drawing. The stop bar is fabricated from flat bar stock and rounds. It is centered on an anchor rod which is guided inside a tubular mounting bracket welded to the uppermost track supporting angle. A safety collar welded to the lower end of the center pin anchors it axially as the 3/4" self-locking nut is tightened, pulling the stop bar down into the top plate of the center pin anchor bracket.

This nut is rendered captive on the center pin by a second nut which is locked in place by a rivet. Hence, removal of the stop bar, or accidental loss of the lock nut is prevented without, however, requiring drastic action to permit intentional removal of the stop bar, as, for instance, in the case of a major system overhaul.

The thrust of the rising platform is received by a spring loaded, adjustable stop screw. The spring loading can be varied by backing off or tightening a 1¼ inch hex nut on the threaded extension of the spring plunger, and simultaneously making compensating adjustment of the ½ inch stop screw. The adjustment of the spring loading consists in effect of a variation of the total effective spring deflection. For higher preloading of the stop spring, spacer washers may be installed between plunger and spring.

The rear end of the stop bar serves as a back rest preventing bending stresses at the center pin. That end is, therefore, fitted with an adjustable, locking back rest screw. The screw is backed off until the stop bar has been firmly screwed down by means of the self-locking nut on the center pin. The back rest screw is then advanced until it bottoms firmly on a back rest pad which is welded to the pool liner skin. The screw is now locked in that adjustment, which is left undisturbed whenever the stop bar is switched from one position to the other.

Lower Level Stops

At the end of its downward travel the platform is arrested by stops which are mounted on hydraulic dashpots capable of telescoping by 4 inches. They are normally held fully extended by low-rate coil springs inside the pots. The stainless steel pads bolted to the platform stop brackets, using shims as required, make contact with the dashpots via the ends of 5/8 inch cap screws installed in the top of the dashpot cylinder. As shown in detail in Figure 3-19, the dashpot comprises a mobile cylinder, sliding on and guided by a fixed plunger. The upward travel of the cylinder, raised by a coil spring, is limited by a stop screw arranged at the lower edge of the cylinder skirt.

A narrow slot is milled into the cylinder skirt from the top down. It terminates in a large hole which is positioned at a level above the top lip of the plunger where the cylinder is in its rest position, i.e. fully raised by the spring. Hence, the fluid space above the plunger communicates with the outside water through a large port area. As the cylinder is pushed downward by the descending platform, the communicating port slides past the lip of the fixed plunger, progressively reducing the effective port area. Water in the cylinder above the plunger is being expelled from that space through the port, the effective flow area of which diminishes as the cylinder advances downward. The result is a progressive increase in the resistance the dashpot offers to the descending platform, causing a corresponding gradual braking action.

The stationary dashpot plungers are bolted to reinforced portions of a closed frame made up from structural aluminum angles arranged with the vertical leg down. That frame, in turn, is clamped and pinned to a base frame fabricated from the same material as the upper frame. It is bolted to mounting pads welded to the bottom panel of the stainless steel liner at points directly below the location of the dashpots. The two frames are fastened together by bolt and nut assemblies, incorporating dished spring washers; since the bolt holes in the lower frame are elongated vertically, the top frame is capable of sliding down on the lower frame as soon as the frictional force between them (caused by clamping) is exceeded by a downward thrust.

Low strength dowel pins are installed in holes through the webs of both frames after these have been properly aligned. The pins serve as locating elements, rather than lock dowels, since the upper frame is essentially held in place by the clamping effect of the dished washers. This arrangement affords additional protection against damage to the plaque system in the case of an exceptionally hard landing of the platform.

A crash pad is provided in the rectangular space formed by the aforementioned frames. It serves to cushion the impact of the source subframe, should that part ever have to be jettisoned and allowed to fall free without the use of lowering cables, as outlined earlier, in the case of a "jammed" platform. The crash pad is

Lower Level Stops (continued)

made up of a number of corrugated aluminum sheets laid with the corrugations perpendicular to one another. The uppermost sheet is made larger than the lower ones for a snug fit inside the stop support frame, while all underlying sheets have ample clearance. The close fit of the top sheet is required to prevent slugs or other articles falling into the inaccessible crash pad area. As an additional precaution, all crash pad sheets are made in two sections which overlap in the center. Holes 3/8 inch in diameter in each sheet section permit the sheets to be hoisted to the surface without interfering with the platform track system. The crash pad may, therefore, be disassembled from above should this ever be necessary.

Platform Tracks and Guide Wheels

The platform main frame is guided in its vertical movement by rollers running in four tracks. The tracks are of 2 x 2 x $\frac{1}{4}$ inch stainless steel angle, bolted to supporting brackets at about 3 ft. intervals. These brackets - $2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$ inch stainless steel angle, are bolted to mounting pads which are welded to the pool liner. The arrangement of these pads, which have mounting holes drilled and tapped before welding in position is shown in Figure 3-24. As will be seen from Figure 3-25, the track angles can be adjusted horizontally in the elongated bolt holes of the mounting bracket (perpendicular to the liner wall). In turn the mounting bracket is adjustable parallel to the liner wall, owing to the generous hole clearance of its mounting bolts. These bolts engage the tapped holes in the mounting pads on the pool liner.

The arrangement described affords a considerable range of adjustment for track location, to allow for all expected construction irregularities of the pool liner. It will be apparent that no welding, boring or tapping is required in installation, but solely the drilling and reaming of dowel holes after properly aligning the track system.

Since each track is made up of two sections, each center mounting bracket is adapted for use as a tie member by effectively doubling its length. The corresponding mounting pads are designed to suit the double-length brackets. As described earlier, the uppermost mounting bracket of each track is made considerably longer also, and serves as a mount for the upper level platform stop bars.

The platform guide wheels, machined from round stock, turn on stainless steel pins which are mounted in the arms of a welded yoke. Thin spacer washers position the wheel in the center of the yoke. This, in turn, is mounted on a 1 inch diameter pivot shaft which is supported in a bracket of fabricated construction. Set screws in the bracket lock the shaft in place. Spacer washers are provided to enable lateral adjustment of the wheel yoke and, hence, of the wheel itself while controlling side play between yoke and bracket.

The normal position of the yoke is horizontal, when it will rest on two stop screws permitting convenient adjustment of that position. A shear pin installed in the mounting bracket controls the torque at which the yoke will break away from the normal position. As may be seen clearly from Figure 3-26, the yoke-wheel assembly can only rotate upward. Hence the guide wheels will retract only when they meet an obstruction while the platform moves downward. The wheel should yield when encountering a resistance of 200 lbs. The shear pin will carry the shear force generated by 125 lbs., while the balance of 75 lbs. is borne by a suitably shaped plate spring bearing against a roller mounted in the tail end of the guide wheel yoke. The spring is bolted to the yoke supporting bracket, and may be adjusted by shims, as well as by a pair of adjusting screws. The shape of the spring results in an over-center effect. Hence, the spring assists in locking the guide wheel holder in its normal position. As the torque caused by an obstruction encountered on the way down exceeds 200 lbs. x 6 inches = 1200 in. lbs., the pin will shear and the spring compressed. The yoke roller eventually passes over the high point of the spring and the guide wheels comes out of the track. The yoke and guide wheel assembly is then held in a retracted position.

The yoke supporting brackets are mounted on gusset plates which are welded between side and end members at each corner of the platform main frame as described earlier. Elongated holes permit individual adjustment of each yoke assembly toward or away from the tracks. Dowel holes are then drilled and reamed to locate the brackets positively.

Platform Hoisting System

The platform is suspended from four ¼ inch diameter stainless steel wire rope cables. The cables are attached to stainless steel drums of welded construction, arranged in two parts on two drum shafts of 2 inch diameter. The design features of the drums, as well as the mode of anchoring the ends of the suspension cables are shown in Figure 3-27. Also indicated on that drawing is the take-up feature permitting the permanently attached cable end in the drum to be anchored in either of two positions. This in addition to the stepless adjustment feature provided by the screw type cable end fitting at the other extremity of the cable, affords a generous degree of freedom in adjusting the suspension cables.

Each drum shaft is supported in two anti-friction pillow block bearings. These bearings are secured to vertical mounting pads which are bolted to brackets welded to the pool liner. The brackets are L-shaped; the weight of the platform is thus borne by the horizontal leg of each bracket, which, in turn, rests on and is welded to a reinforced section of the liner. As may be seen from Figures 3-18 and 3-24 the pool liner is recessed along the rim on the two 8 ft. long sides. The recesses permit installation of the drum shafts at a lower level, resulting in the complete absence from the cell floor of any shafts, bearings, or gear boxes; these are all well below floor level. The bearings are fully adjustable vertically and also permit some horizontal adjustment.

The ends of each drum shaft are connected via self-aligning couplings to the output shaft extension of two right-angle gear drives having one to one transmission ratio. The drives are to selected and arranged that their output shafts will turn in opposite directions when their input shafts are driven in the same direction. As shown in Figure 3-28 the two gear boxes are mounted with their input shafts in-line, permitting the installation of a connecting shaft between them, again using self-aligning couplings. The gear boxes are installed in wells, below floor level. These wells and the trenches provided for the drum shafts and the connecting shaft are closed by removable covers. The covers over the gear box wells have a 2 inch thick lead lining in order to reduce the radiation intensity inside the gear boxes to a level compatible with the radiation resistance of the lubricants used.

The input shaft of the first gear box is coupled to the main drive shaft. This 3 inch diameter shaft is made up of two sections, supported in three anti-friction pillow block bearings and inter-connected by self-aligning couplings. The shaft assembly runs first in a covered trench, then through a tunnel under the cell wall to emerge in the Equipment Room. A lead collar around the shaft is provided in the tunnel to safeguard against stray radiation leaking out of the cell.

The end of the main shaft supports a shaft-mounted gear reducer, (Falk 315T25), between two pillow block bearings. The reducer is powered by a 2 HP, 1150 RPM motor with shaft mounted fail-safe brake. The motor is mounted on top of the reducer, which it drives via a chain drive. Two independent chains, each with its own sprockets, are used.

Since each chain drive alone is more than adequate to provide fully reliable operation, near complete safety against a mishap owing to chain breakage is insured. The chain drive ratio and the speed reduction in the shaft mounted reducer combine to step the speed of the drive motor (1150 RPM) down to 6 RPM. That speed, which is maintained right to the drum shafts, results in a platform speed of approximately 10 f.p.m., or about 2 inches per second.

Platform Hoisting System (continued)

The torque reaction of the shaft-mounted drive assembly is balanced by a 300 lbs. weight suspended at a distance of 28.7 inches from the center of the gear reducer output shaft (main drive shaft). In order to maintain a constant balancing torque of 8600 in lbs. the 300 lbs. weight could be replaced with 720 lb. one, attached to a segment of 12 inch radius about the center of the main drive shaft. The weight would be suspended from a chain which, after passing over an idler sprocket would be attached to the far end of the guide segment.

The constant torque thus generated balances the normal drive torque represented by the product of the weight of the loaded platform (2200 lbs.) multiplied by the radius of the cable wind-up drums (3¼ inch) and corrected for the expected losses in the mitre-gear drives, bearing and cable friction, etc. by multiplying by a factor of 1.2. This amounts to 8600 in lbs. Any change in torque, as brought about by a material change in the tension of the suspension cables, will now cause the reducer to rotate about its output shaft center. Limit switches are placed in such a way that they will be actuated by the reducer at the end of a pre-determined arc of travel. Tripping of the switch interrupts the drive motor current, simultaneously de-energizing the brake hold-open solenoid and causing the brake to lock the motor shaft.

As soon as the equilibrium of the drive system is disturbed causing the shaft mounted reducer to tilt, a new balancing torque component is established by one of the two secondary counterweights being lifted from their rest positions. It will be seen from the drawing that these secondary counterweights tend to return the reducer to its neutral position. The torque created by them (one weight only can be active at any one moment, and only when the drive torque varies) tends to oppose the unbalancing torque. Hence the reducer will begin to tilt only after the imbalance in the platform system overcomes the balancing torque. Using 25 lb. weights at 12 inches from the output shaft center, the unbalancing movement will have to exceed 300 in. lbs. in order to permit the reducer to tilt. Referred to the normal running torque of 8600 in lbs., this is 3.5%. In other words, therefore, a change in the normal running tension of the four suspension cables of 3.5% will cause the reducer to tilt on its mounting shaft and, after rotating through a pre-determined arc, trip one or other of the limit switches.

The mounting arrangement described, permitting detection of over and underloads, is also utilized in stopping the platform at its scheduled upper and lower end positions. At the lower station, the descending platform is set down on hydraulic dashpots which retard its descent. This reduces the apparent weight of the platform as registered by the suspension cables which are still paid out at the original rate. The reduction of the lowering torque now permits the torque balancing system to tilt the reducer on its shaft until it trips the low-torque limit switch, which, in turn, shuts off the drive motor, and applies the brake. The net result is a slowing down in the speed of descent of the platform by the dashpots mounted on a fixed frame on the pool floor, followed by a complete stop by means of the motor shut off. Following this, the full weight of the now motionless platform is again borne by the suspension cables, restoring the normal torque at the drive shaft. The shaft-mounted reducer, therefore will again return to its normal position.

At the upper station, the platform approaches spring cushioned stops. The tension of the suspension cables increases at the cushioning springs are compressed. This causes the gear reducer to begin to tilt on its shaft, and consequently, slow the speed of ascent of the platform. The cushioning springs "bottom" eventually, and the platform is arrested completely. The reducer now continues its tilting motion at an accelerated rate until it trips the high-torque limit switch, thus stopping the motor and applying the brake.

The end of the main drive shaft beyond the reducer outboard bearing is fitted with a screw and nut type follower system. The nut will control a potentiometer, permitting remote indication of the platform position. At either end position, the nut trips a limit switch which is tied in with the electrical safety interlock system described elsewhere.

Jig Plate Design

It is planned that the jig plates supplied initially with the radiator will provide for use of the source in two configurations.

a. Single pass two plaque irradiator.

b. Double pass single plaque irradiator.

The jig plate for a single pass irradiator is shown in G1 of Figure 3-13. The jig plate is split into two halves to permit adjustment of the distance between the two plaques so that packages with thicknesses from 5" to 24" (plaque center line spacings from 8" to 27") may be irradiated using the maximum dose rate available. The jig plate for the double pass, single plaque irradiator is shown in Figure G2. It simply utilizes 1/2 the jig plate of the single pass irradiator and employs a second set of mandril holes as shown in Figure. For the double pass, single plaque irradiator the jig plate is moved 1/2" in (at right angles to the direction of package motion) so that the center line of the radiator is maintained at the same distance from the center line of the conveyor pass.

In the event a cylindrical source configuration is to be employed sometime in the future, the design will be similar to the pattern shown in G3 of Figure 3-13.

V. SOURCE TANKS AND POOL WATER CONTROL

General:

The source receiving pool, 8' x 10' x 23½' in depth, is provided on the outside of the cobalt cell for the receipt and transfer of the cobalt 60 shipments. The cobalt 60 is expected to be shipped from Savannah River in a 15 ton cask, which will be lowered to the bottom of the receiving pool by means of a portable crane. Slugs will be removed from the cask and transferred to the inner cell pool via a connecting chute inclined at an angle of 27°. To protect the source slugs, it is envisioned that they will be mounted in a small protective can to prevent scratching during transfer. At the bottom of the chute a catch-can automatically catches and tilts the slug into a vertical position for handling in the pool. A similar transfer tube with the reverse slope is provided for transfer from the cell pool to the cask pool. Details of construction may clearly be seen from Figures 3-29 and 3-30.

Both pools are constructed of type 304 stainless steel, reinforced, with a ¼" wall thickness and 3/8" bottom thickness. Joints between tank plates are full penetration double welded butt joints, developing a joint efficiency of at least 85% of the plate strength. Welds were spot inspected using radiographic means. In addition, each tank was subjected to a hydrostatic test prior to applying the final external finish. This consisted of filling the tank completely with water and allowing it to stand for six hours. During this time all welds were carefully examined for leakage, and all leaks repaired.

After fabrication, all exterior and interior surfaces were thoroughly cleaned to remove all weld spatter, mill scale and foreign matter, and all exterior carbon steel surfaces were wire brushed prior to the application of the prime coating. Primer and hot enamel bitumastic coating were applied to outer surfaces, with the final coat a minimum of 3/32" thick. A Holiday or Spark test was performed to insure total coverage of the finished paint.

Reinforcement of each stainless steel tank consists of twelve circumferential 8-inch I beams as indicated in Figures 3-29 and 3-30. Each tank rests on six 6-inch I beams which, in turn, rest on a footing 2' - 2" thick and 12' x 38' - 8". The tanks are bolted securely to the footing and compacted fill placed around them to ground level. The elevation of the bottom of the tanks is 143' - 0", compared to the lake elevation of 138.4'.

All materials were new and of first quality, and fabrication was performed in accordance with requirements of the various applicable construction and testing codes.

The transfer tubes, each 19' - 8" in length and one foot in diameter are of welded type 304 stainless steel. They are inclined at an angle of 27° to permit the gravity transfer of slugs from one pool to the other. Static tests on a mockup of the system indicated no problems regarding the slugs becoming impeded during their transit. If, however, this situation were to occur, movement would again be started by inserting a flexible rod or cable to push the element along.

The two interconnecting pipes were field cut, put in position and welded after the pools were shimmed carefully to the correct elevation, plumbed, and leveled and bolted down. After completion of all welding, the welds were hydrostatically tested at 20 psig for a period of one hour, and all leaks repaired.

Provision is made for sealing the mouths of the transfer tubes when not in use to prevent movement of water from one pool to the other. However, even during transfer of slugs, this movement is a minimum, and impurities introduced into the inner pool can be quickly removed by the filtering and demineralizing units. This feature also allows for the storage of the source in one pool should the necessity arise which would require the emptying and refilling of the second pool.

Cask Pool

The cobalt 60 receiving pool is provided with a gasketed metal cover that may be locked to prevent access by unauthorized personnel. In addition, this also acts as a dust cover.

The primary purpose of this pool is to provide a suitable receptical for the shipping cask and the transfer of the cobalt 60 into the inner cell pool. Even though the time interval that the slugs will remain in the outer pool is a minimum, the water purity of this pool will be maintained at the same level as that in the inner pool.

Natural convective currents within the pool will keep the water from freezing during exceptionally cold weather. In the event, however, of unseasonably frigid weather wherein an extreme amount of pool freezing were expected, underwater devices are readily available for use at several of the nearby Quartermaster facilities. It should be noted that weather conditions which would necessitate the use of external heating measures are highly unlikely; however, provision has been made for the possibility of the occurrence.

Provision is also made in the water treatment system for testing individual sub-assemblies for radioactive leakage: the suspected slug is placed in a small container open at the top. A pipe runs from the bottom of this compartment to the deionizer, permitting water to flow over the slug and into the deionizer for monitoring.

The arrangement described enables leakage checks to be performed efficiently and expeditiously on single source sub-assemblies. Such checks may be scheduled for any sub-assemblies prior to its being loaded in the plaques. This will reveal any suspected damage to a source element which may have happened during shipment or unloading. It will, of course, also permit convenient checking of the individual sub-assemblies whenever, after any length of regular operation, the radioactivity monitor indicates appreciable cobalt contamination.

Cell Pool

Temperature Control

When the 1.38 megacurie source is stored in the pool, essentially all of its 20 kw of radiation energy ends up in the water, either by direct absorption of the gamma radiation or by conduction from the walls and floors. This heat would raise the average water temperature at a rate of 0.5°F/hr. If no provision for cooling is made, the water temperature would rise to 175 or 200°F before the heat losses by conduction through the concrete and convection from the surface balanced the heat input. For a three megacurie source the heating rate is 1.2°F/hr and the water would boil before heat losses balanced heat input.

Provision is therefore made for keeping the pool water at a temperature close to ambient by continuously circulating a small stream through a heat exchanger, where it is cooled by water from the lake. A flow of 18 gpm is sufficient to keep the pool at a constant temperature of 100°F, assuming it leaves the cooler at 82°F.

A schematic of the pool water treatment system is shown in Figure 3-31.

Water Purification and Control

The selection of the outer aluminum can was predicated on strict control and purity of the water surrounding the source tubes. To minimize corrosion of the aluminum it is necessary to maintain the following water conditions:

a. Demineralized water essentially free of heavy ions

b. Maintain chloride content below 1 ppm

c. Maintain pH between 6.5 and 7.5

d. Eliminate presence of dissimilar metals in the immediate vicinity of the aluminum capsules

e. Maintain resistivity at 0.5×10^6 ohm-cms.

Each of these conditions will be met utilizing various equipment located externally to the inner cell, excepting d.

Pool Water De-Ionization

To provide early warning of a leaky capsule and to minimize dust and other foreign matter, the water of the pool system is continuously circulated through a de-ionizing and filtering system which incorporates monitors to measure the radioactivity level as well as the ionic concentration.

The de-ionizing system is designed to accept pool water at the rate of 5 GPM. At a total water volume of approximately 4000 cu. ft., that rate of circulation would represent one complete turn-over in about 100 hrs. Since, however, the intake is located in the cell pool in the vicinity of the plaques, in their fully lowered position, the circulating action will be limited to the water in that pool, amounting to approximately 2000 cu. ft. The rate of circulation will then result in one complete turn-over every 50 hours. The mode of operation and the bulk of the equipment involved, such as piping, fillings and flow monitoring and controlling organs may be readily obtained from a study of Figure 3-31.

A radiation monitor is fastened to the de-mineralizer shell near its mid-line and is adjustable in position. In the presence of a preset level of radioactivity in the de-mineralizer, it flashes a warning light at the annunciator panel.

The pool heat exchanger is of the shell and tube type with a capacity of 160,000 BTU per hour. An intake rate of 18 GPM of pool water at 100°F will discharge the water at 82°F. Condensor water, to be taken from the nearby lake at an inlet temperature of approximately 72°F, will be discharged back into the lake at a temperature of 87°F at a flow rate of 22 GPM. The condensor shell is of carbon steel construction while the tubes are stainless steel.

The pool circulating pump, the use of which is shown schematically in Figure 3-31, is a contrifugal type with a capacity of 23 GPM. It is approximately ½ horse power with stainless steel impeller and casing. The pool booster pump is similar, but with a capacity of 5 GPM.

Water for the initial filling of the pool will require expending a much higher number of filter cartridges than is expected during normal operation later on. In order to save time in the treatment of the initial charge of water, the demineralizer to be employed in the accelerator cooling system will be utilized to provide demineralized make-up water which is then passed through the pool demineralizer before flowing into the pool.

A water level of several inches below the recommended water level is not significant as far as dose rate at the pool surface. Therefore it is proposed that replacement water in the pool, to make up for evaporation losses, will be added manually every several days, or as required.

VI. SOURCE TESTING PROCEDURES

Source Selection Criteria

The Curtiss-Wright HIFI design originally considered the use of a strip source. However, as mentioned previously, rods were chosen for the FPDI design primarily because their symmetry would simplify source arrangement, provide a greater ease in rearrangement, add more flexibility to source arrays possible and prove easier to fabricate. With this arrangement, it is easily possible to form an array, for instance, where small source volume and high dose rate are desirable. While it is realized that some efficiency must be sacrificed, this consideration became secondary to the aforementioned advantages to be gained in the cylindrical source.

In considering the outer aluminum cladding, it was necessary to evaluate possible physical changes which could occur and control measures which would be required to insure that this cladding was adequate to prevent contamination from the cobalt source. Operation of the source requires that the slugs remain in air during the radiation exposure process, then be immersed into the source pool for storage. Several potential problem areas considered in the selection of the aluminum included corrosion, pitting, thermal integrity, and possible electrolytic action. Each of these is discussed in more detail with, where appropriate, recommended measures to be taken to control or minimize undesirable action.

It was realized, before selection of the chosen capsule, that certain problems had confronted other potential users of a cobalt source utilizing an outer aluminum cladding. Among these were the English, who attempted to develop a doubly encapsulated source of first a stainless steel, and then an outer aluminum cladding. Original cobalt material was 2 curies per gram, and new material $4\frac{1}{2}$ curies per gram. After an attempt to use aluminum, a double stainless steel encapsulation was chosen. This was due to both the consideration of a future source of supply, for which stainless steel was felt to be more compatible, and to unfavorable experience with the cladding due to its nominal purity and the unknown optimum environmental conditions in which the source should be maintained.

Through contact with several of these organizations and individuals having prior experience in a capsule with an outer cladding of aluminum, the consensus was that if certain minimum criteria in both aluminum purity and storage conditions were met, that the integrity of the aluminum, and hence of the capsule, would be maintained. Curtiss-Wright, in developing this source, was successful in obtaining a grade of aluminum which would fulfill the conditions of the first requirement. An analysis of this alloy, known as type 1245, can be found on page 3-76. The pool water conditions to be maintained were outlined in section V and conform to the recommendations received.

Another potential problem considered in the selection of this source was the possible pitting of the aluminum due to ozone. This could be most serious when the sources were raised out of the pool, still damp, and brought into the radiation position. As previously noted, however, four of the ten-inch slugs will be stacked into an aluminum source holding tube. This tube is provided with drain and vent holes to allow for the rapid dissipation of both water and vapor from its interior. The slug temperature will be in the neighborhood of 300°F (see page 3-16) upon its withdrawal from the water. These factors coupled with the designed ventilation characteristics are sufficient to allow for almost instantaneous drying and dilution and purging of ozone away from the source. Pitting from this potential area will not present a serious problem.

(Ventilation characteristics and criteria are presented in Part I of the license request on page 1-18 for the cobalt 60 cell. Under normal conditions, the cell ventilation corresponds to approximately 50 air changes per hour.)

To confirm source integrity insofar as thermal cycling is concerned, testing was conducted at the Army's Watertown Arsenal. A summary of these results is in a later paragraph of section VI. Our primary concern, in this regard, was to confirm both cladding and weld integrity, to insure that end caps would not pop out. An inherent feature in the design of this capsule is that the expansion coefficients of cobalt, stainless steel, and aluminum are in the proper order, so that the cobalt expands the least. In summary of this point, the testing at Watertown, while not duplicating exact operating conditions, was sufficiently close to suggest assurance that the aluminum and stainless steel claddings would withstand the normal operating thermal stresses.

The corrosion of cobalt was still another potential problem area which required study. A literature search on the corrosion resistance of cobalt was undertaken at the New York Public Library and Engineering Societies Library, using the following reference sources:

Nuclear Science Abstracts	1951-1960
Chemical Abstracts	1917-1957
Cobalt Abstracts (1)	1958-1961
Engineering Index	1945-1959
ASM Review of Metal Literature	1944-1959
Applied Science and Technology Index	1958-1960
Library Card Catalog of each Library	

(1) Published in "Cobalt", a new magazine consisting of 10 issues up to March 1961.

Results of this search can be summarized as follows:

In spite of the present importance of cobalt, relatively little information is available on the resistance of this metal to corrosion; the chemical literature of the past 25 years contains only scattered references to corrosion studies in which cobalt is included, and these are sometimes contradictory. The only applicable corrosion data found were obtained by Young* and the data are reproduced in Table 3-I. The corrosion for pure cobalt in distilled water is given by Young as 1.1 mg/dm^2/day. A general listing of corrosion resistance of cobalt as determined by various investigators in earlier research is given in Table 3-II. A bibliography in which the pertinent observations of investigators are reported, including a comprehensive bibliography obtained from Batelle Memorial Institute, is available upon request.

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* Young, R. S., "Corrosion Resistance of Cobalt", Corrosion Technology 4, Nov. 1957, 396-397, 403.

Tests are described to obtain quantitative data on corrosion resistance of cobalt in typical dilute mineral acid, organic acid and base, and the corrosion rate of heated and unheated samples of cobalt. The corrosion data of 22 x 26 x 1.5 mm cobalt corrosion specimen immersed for 42 days in 100 ml of solution is reported in Table I.

Young, R. S., "Resistance of Cobalt to Certain Solutions", Corrosion Technology 6, Mar. 1959, 89

This is a continuation of the test work on cobalt corrosion. In these tests, the samples were immersed for 31 days; the data is reported in Table I.

Table 3-I

Corrosion of Cobalt at 25°C in Quiet Immersion
(All corrosion rates are reported in mg/sq dm/day)

Reagent (% by volume)	No Preheating of Sample	Sample Preheated in Air				Sample Preheated in Nitrogen			
		300°C	500°C	700°C	900°C	300°C	500°C	700°C	900°C
5% Acetic Acid	12.5	10.4	11.9	29.9	46.2	28.4	26.5	28.4	22.7
5% Ammonia	5.3	2.5	4.9	0.8	0.9	2.3	4.2	4.9	5.1
5% Sulfuric Acid	56.8	25.9	26.5	54.9	68.2	42.6	64.4	53.0	28.4
5% Hydrazine	7.8								
10% Sodium Hydroxide	5.6								
Conc HF	101.5								
50% HF	178.6								
Conc Phosphoric Acid	7.4								
50% Phosphoric Acid	65.1								
Distilled Water	1.1								

Table 3-II

Corrosion of Cobalt in Various Media

Corrosive Media	Observed Result
Sulfur monochloride	Unattacked
Sulfurous Acid	Attacked
Aqueous Ammonia, 10 - 70%	"
Ammonium persulfate	"
Citric Acid	"
Chlorine Water	"
Formic Acid	Unattacked
Magnesium Chloride	Attacked
Rain Water and Air	"
Methyl Alcohol	Unattacked
Methyl Alcohol & 2% Formaldehyde	"
Methyl Alcohol & 1% Formic Acid	Attacked
Methyl Alcohol & 25% Sea Water	"
Methyl Alcohol & 20% Water	"
Oleic Acid (90 - 100°C)	Unattacked
Potassium Persulfate	Attacked
Sea Water	"
Sea Water & Air	"
Selenium Oxydibromide	Unattacked
Sodium Hydroxide (10 - 50%)	Attacked
Sodium Sulfide (10 - 50%)	"
Tartaric Acid	"

In evaluating the experiences of others in developing a source slug appropriate for use in this radiation laboratory, the doubly encapsulated source as described herein was chosen. It was realized that several others had had partial bad experiences with aluminum cladding, and by obtaining their suggestions and solutions a workable source has been developed. It is a foregone conclusion that reasonable precautious and operational maintenance procedures must be strictly adhered to in order to assure continued successful use of the source.

The greatest deterrent to danger lies in the monitoring of two source slugs which will be fabricated and irradiated well in excess of a year prior to the source slugs for the FPDI. Indications of trouble with these slugs will forewarn of danger to the actual source.

Savannah River Acceptance Criteria for Slugs

Encapsulation specifications for the cobalt slugs were established jointly and agreed upon by Curtiss-Wright, du Pont, and Savannah River Operations Office. Actual encapsulation procedures and material specifications are outlined in Section III of this report.

Cobalt slugs are produced by Curtiss-Wright and are sent to SROO in lots of seventy-five. The first lot was shipped during the latter part of April 1961, with five subsequent lots of seventy-five to be shipped in intervals of approximately three weeks. A technical representative of du Pont is to be present at Curtiss-Wright during all of the encapsulation. The representative is to have the authority to reject slugs at any point in the fabrication process when, in his opinion, there is doubt as to the integrity of the slug.

Out of each group of slugs, SROO will choose 10%, or 8 slugs, and destructively test them to insure adherance to the manufacturing specifications. If any of the eight fails to meet all inspection criteria, the entire lot can be rejected.

At Curtiss-Wright's request, Savannah River furnished the following inspection and rejection criteria to be used in determining that cobalt slugs were acceptable for irradiation:

1. Each slug must meet dimensional specifications as outlined below or it will be rejected:

Dimensions in inches

Cobalt	OD	0.725 ± 0.0005
SS can	ID	0.725 ± 0.001
SS can	OD	0.765 ± 0.001
Al can	ID	0.765 ± 0.001
Al can	OD	0.943 ± 0.002
Cobalt	L	10.250 ± .002
SS can	L	10.330 ± 0.002
Al can	L	10.699 ± 0.005

To insure that the heat generated in the cobalt while under irradiation can be removed, it is necessary that diametrical clearances between the cobalt and stainless steel can and between the stainless steel and aluminum cans be kept to 0.001 inches or less.

2. Each slug must be leak tight as determined by a bubble test or it will be rejected.

3. Ten percent of the slugs produced will be destructively examined by sectioning the slug at about 2.5, 5, and 7.5 inches from one end. A surface at each cut will be polished and the diametrical gap between the cobalt and stainless steel and between the stainless steel and aluminum will be measured at 0°, 90°, 180° and 270° with a Standard Tukon Hardness Tester microscope. If the average of the four measurements of the diametrical gap on any one of the polished surfaces exceeds .001 inches, the entire batch of slugs will be rejected.

4. Since a bubble test will not verify the integrity of the stainless steel welds, the welds on 10% (ten percent) of all slugs will be sectioned and examined for defects.. One defective weld will be cause for rejecting the entire batch.

5. The outside of the aluminum can on each slug must be free of dents, scratches or gouges greater than .010 inches on lateral surfaces, greater than .020 inches on the end cap, and greater than .005 inches on the weld bead or the slug will be rejected.

6. Throat thickness of the stainless steel and aluminum welds must be greater than .010 inches or the slug will be rejected.

7. The height of the aluminum welds must not exceed the height of the boss or the slug will be rejected.

8. Each sectioned part of each slug will be examined for foreign material and if detected will be sufficient cause for rejecting the entire batch.

Foreign materials, such as lubricants and organic cleaning agents which deteriorate and release gas when exposed to high gamma fluxes, must not be enclosed in the stainless steel or aluminum encapsulation cans. If a sufficient quantity of a suitable material were enclosed in one of the cans, internal gases could conceivably generate, rupture the cans, and permit release of cobalt to the reactor coolant system.

Curtiss-Wright Testing Procedures and Fabrication Standards

After an evaluation of the Savannah River acceptance criteria for the cobalt slugs, Curtiss-Wright set for themselves standards of fabrication and quality control which would severely limit rejection of any batch of slugs, or even of any individual element. An evaluation of several test slugs by Savannah River, described in a later paragraph of this section, also aided in the establishment of the standards ultimately selected.

The actual chemical analyses of materials used in the fabrication of the FPDI slugs are outlined below. (see page 3-32).

a. Aluminum tube and aluminum end caps, both alloy type 1245:

Element	Max %	Element	Max %
Al	99.45	Cu	.04
Mn	.03	Bi	.01
Mg	.01	Pb	.01
Cr	.03	Sn	.01
Ni	.01	Li	.008
Zn	.03	Cd	.003
Ti	.03	B	.001
Si	.50% of iron	Co	.001

b. Stainless steel, type 304 seamless tube and end caps: (see page 3-31)

Element	Max % in tube	Max % in end caps
C	.07	.054
Mn	1.47	1.16
Phos	.013	.017
S	.012	.015
Si	.38	.73
Ni	10.44	9.18
Cr	18.86	18.92
Co	.09	
Zn	$<$ .005	

c. Four lots of reactor grade cobalt cylinders where chemically analyzed as follows: (see page 3-29).

Element	% in Lot 1	% in Lot 2	% in Lot 3	% in Lot 4
Co	98.12	97.73	97.68	97.86
Ni	.59	.75	.76	.70
C	.085	.08	.08	.09
Cu	.04	.04	.02	.02
Fe	.625	.51	.52	.51
Si	.17	.48	.48	.48
Mn	.37	.51	.26	.24

Specifications for dimensions of the slugs at various stages of encapsulation are shown in Figures 3-3 through 3-12. Exacting procedures were developed and used to insure dimensional correctness at all points of the fabrication and encapsulation.

Two of the more critical quality control inspection criteria are the leak tests performed after each stage of the two-stage encapsulation. The slug is immersed in kerosene in the test chamber which is evacuated to a vacuum of 26 inches of mercury and held for one minute. During evacuation and hold time any evidence of a bubble stream from a given point was reason for rejection. After each of these tests, destructive testing was performed on five percent of randomly selected slugs. In the first case, weld quality of the stainless steel weld was inspected, while in the second case weld quality and tightness of envelope contact was inspected. A more detailed quality control inspection plan is included on the next page, and was utilized in conjunction with the fabrication procedures described on pages 3-28 through 3-39.

After a final inspection to insure compliance with outside physical dimensions, both ends of the slug are engraved with a code number, packaged and shipped to Savannah River for further inspection prior to activation.

Curtiss-Wright
Encapsulation Inspection Plan

Inspection point	Function	Frequency
Receipt of material	Identification to Purchase Order	100%
	Dimensional Check	MIL STD 105 Sampling Table
Sub-contracted Parts	Material Check	100%
	Dimensional Check	MIL STD 105 Sampling Table
Detail Fabricated	Material Check	100%
	Dimensional Check	MIL STD 105 Sampling Table
1st Stage Encapsulation	Dimensional Check	MIL STD 105 Sampling Table
	Leak Test of Welds	100%
	Visual	100%
	Destructive tests	5%
2nd Stage Encapsulation	Dimensional Check	MIL STD 105 Sampling Table
	Leak Test of Welds	100%
	Visual	100%
	Destructive tests	5%
Outgoing Inspection	Final Acceptance	100%
	Packaging	100%

Savannah River Evaluation of Test Slugs

In attempting to develop a satisfactory production line procedure for the manufacture of the required 450 slugs to be produced, and at the same time maintain the quality control at a high level, Curtiss Wright cooperated with SROO in the establishment of an appropriate and ultimately acceptable production procedure. During the latter part of 1960 Curtiss Wright sent two small groups of slugs to SROO for their evaluation and comments. Welding standards and encapsulation parameters were still under development at this time, and these groups of test slugs were not of an acceptable nature due to poor welds, diameter variations, or excessive gaps within the slug.

During a visit by SROO representatives to the Curtiss Wright Corporation during January 1961, six more sample slugs were fabricated on a production line basis. These were forwarded to SROO, where four were to undergo destructive examination and two were for pilot irradiation. Destructive examination showed the slugs to be of acceptable quality. Slug O D was satisfactory, but all were at least 0.045 inches longer than the specified maximum permissible length. Since this additional slug length could be tolerated, the two designated slugs were irradiated in the P-6 reactor cycle. Primary purpose of this irradiation was to confirm theoretical activation analysis. A more detailed account of post irradiation testing is described in a later part of this section.

Destructive test data is taken from a letter of February 21, 1961 from the Reactor Technology Section, SRP of du Pont, to the Manager, SROO. Results of the destructive testing of the four slugs is summarized in the following four tables. To hold the O D tolerances and to meet gap specifications on the cobalt slugs, Curtiss Wright installed equipment to permit die-sizing of the final assembly. Slugs produced by die-sizing had total diametrical gaps within the current specification of 0.004 inch maximum (Table II). Slug diameters were within 0.9390 ± 0.0005 inch (specification 0.940 ± 0.002 inch).

All of the slug lengths exceeded specifications (Table I) due in part to longitudinal gaps (average total gap was .020 inch per slug). Large longitudinal gaps are acceptable as almost all heat transfer is radial.

Weld throat thickness was adequate (Table III) and all slugs passed the kerosene leak test.

The cobalt appeared to be free of defects except centerline porosity and, in one case, off-center porosity.

The heights of the bosses in the center of the slug caps were sufficient to protect slug welds during irradiation.

The test slugs were numbered X-9 through X-14, with X-13 and X-14 irradiated in the P-6 reactor cycle. These slugs were identified on both ends by a 3 and 2 respectively.

Table I

SLUG LENGTH

Slug Number	Length inches
X-9	10.701
X-10	10.700
X-11	10.702
X-12	10.770
X-13	10.700
X-14	10.701
Specification	10 5/8 ± 1/32

TABLE II - GAP DETERMINATIONS

Transverse Sections

Gaps - thousandths of an inch

Position, degrees:	End* 0	End* 180	End* 90	End* 270	Middle 0	Middle 180	Middle 90	Middle 270	End* 0	End* 180	End* 90	End* 270	Avg.
Location													
Slug No. X-9													
Al can to SS can	0.1	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
SS can to core	0.2	0.7	1.3	0.6	0.0	0.2	0.0	0.1	0.2	0.0	0.4	0.6	0.4
Total	1.7		2.1		0.2		0.1		0.2		1.0		0.7
Slug No. X-10													
Al can to SS can	0.2	0.3	0.1	0.1	0.1	0.2	0.4	0.1	0.0	0.0	0.0	0.0	0.1
SS can to core	0.6	1.4	0.9	0.1	0.2	0.4	0.5	0.5	0.5	0.0	0.0	0.0	0.4
Total	2.5		1.2		0.9		1.5		0.5		0.0		1.1
Slug No. X-11													
Al can to SS can	0.0	0.4	0.0	0.0	0.1	0.1	0.5	0.1	0.0	0.0	0.1	0.0	0.1
SS can to core	0.5	0.1	0.5	0.0	0.7	0.2	0.3	0.3	0.3	0.0	0.1	0.0	0.3
Total	1.0		0.5		1.1		1.2		0.3		0.2		0.7
Slug No. X-12													
Al can to SS can	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0
SS can to core	0.4	0.1	0.3	0.4	0.5	0.3	0.2	0.2	0.1	0.2	0.4	0.2	0.3
Total	0.6		0.8		1.0		0.6		0.3		0.6		0.6

* Samples located two and one-half inches from ends of slugs.

Longitudinal Sections
Ends of Slugs

Location	Slug No. X-9 left side		Slug No. X-9 right side		Slug No. X-10 left side		Slug No. X-10 right side		Slug No. X-11 left side		Slug No. X-11 right side		Slug No. X-12 left side		Slug No. X-12 right side	
Al can to SS can	0.5*	0.3**	0.3	0.5	0.1	0.1	0.1	0.1	0.6	0.1	0.3	0.3	0.0	0.0	0.0	0.0
SS can to core	0.2	0.7	0.3	0.4	0.1	0.2	0.2	0.1	0.4	0.1	0.6	0.3	0.0	0.0	0.0	0.2
Al cap to SS cap	6.8+	7.0++	8.0	8.0	4.5	7.2	6.5	9.0	2.0	3.0	8.3	3.0	6.0	3.0	4.0	3.0
SS cap to core	5.0	4.0	2.0	2.0	4.0	4.5	5.0	7.0	11.5	5.0	1.5	3.5	5.5	3.0	3.0	7.0

* 3/8 inch from end of core
** 5/8 inch from end of core
\+ 1/4 inch from axis
++ 1/8 inch from axis

TABLE III

WELD THROAT THICKNESS

Inch

Location	Slug No. X-9 left side	Slug No. X-9 right side	Slug No. X-10 left side	Slug No. X-10 right side
Al can	0.034	0.053	0.039	0.028
SS can	0.017	0.017	0.017	0.018

Slug No. X-11 left side	Slug No. X-11 right side	Slug No. X-12 left side	Slug No. X-12 right side
0.026	0.052	0.043	0.034
0.019	0.016	0.018	0.019

Note: **The throat thicknesses of Bldg. 320-M slug welds run between 0.015 and 0.060 inch. Specification, 0.010 inch minimum.**

TABLE IV

CAN WALL THICKNESS

Inch

Can	Max.	Min.	Avg.
Aluminum	0.090	0.087	0.088
Stainless Steel	0.020	0.017	0.019

Watertown Arsenal Thermal Testing

Abstract

Two cobalt encapsulations of the type which will be used in the Food Process Development Irradiator were thermally cycled for the Atomic Energy Commission. The encapsulations were heated in an oven at 600°F and quenched in 40°F water for a total of 100 cycles. Examination after cycling showed no evidence of deterioration or loss of integrity of the welded caps of either the aluminum cans or the stainless steel tubes.

Purpose and Scope

Thermal cycling tests and examination of two sample cobalt encapsulations were undertaken by Watertown Arsenal Laboratories at the request of the Reactor Division, New York Operations Office of the U. S. Atomic Energy Commission. The capsules were of the type which will be subsequently activated and will comprise the megacurie cobalt-60 source for the Food Process Development Irradiator for the Quartermaster Corps at Natick, Massachusetts.

In use, the capsules will be self-heated to approximately 400°F. and periodically lowered into a pool of water which may be as cold as 40°F. It was the purpose of the present tests to determine the integrity of the welds after this type of thermal cycling.

Each encapsulation consisted of a reactor-grade cobalt rod sealed in a tight-fitting type 304 stainless steel tube (with welded stainless steel caps on both ends) which in turn was sealed in a high purity aluminum can (with welded aluminum caps on both ends of the final assembly). The approximate overall dimensions of each encapsulation were 1" diameter by 10-5/8" long.

The canning operations had been performed at the Princeton Division of the Curtiss-Wright Corporation.

Test Procedure

a. Thermal Cycling

Conditions for the thermal cycling tests were prescribed by the AEC. The capsules were heated in a controlled temperature oven at 600°F and quenched in 40°F water for a total of 100 cycles.

The capsules were supported in a holder fabricated at Watertown Arsenal Laboratories. This consisted of two stainless steel tubes of 1/16" wall thickness joined together by welding and provided with a stainless steel wire handle. The upper end of the tubes was fully open while the bottom end was partially closed by means of a welded-on stainless steel ring. The internal diameter of the tube was approximately 1/8" larger than the outside diameter of the capsule.

The oven floor was furnished with two ceramic piers on which the holder and capsules rested horizontally during the heating part of the cycle. The oven temperature was recorded at the end of each heating cycle. Temperatures were maintained between 600°F and 605°F throughout the 100 cycles, except that during the 22d cycle a temperature of only 470°F was maintained as a result of an overloaded electrical circuit.

A period of thirty-five minutes at 600°F was allowed to bring the cobalt core to a temperature estimated to be 400°F, (based on calculations furnished by the AEC). The holder and capsules were then removed from the oven and slowly lowered vertically into a plastic container of water maintained at approximately 40°F. The cold bath temperature was controlled between 40°F and 42°F throughout the 100 cycles, except that during no more than five cycles the temperature was 43°F or 44°F. The speed of immersion was controlled to take approximately five seconds to completely submerge the tubes. The tubes and capsules were dried and at a temperature of approximately 70°F before being returned to the oven.

b. <u>Examination</u>

(1) <u>Fluorescent Penetrant Test</u>

At the completion of 100 cycles all surfaces of the two capsules were first inspected for evidence of cracks and discontinuities using the fluorescent liquid penetrant test method in accordance with specification MIL-I-6866A, Type I.

(2) Helium Leak Test

The aluminum can was removed from each capsule by careful severing at the midpoint, using a cut-off wheel. Both welded ends of each aluminum can were then tested for leaks by connecting the open end of each half to a Veeco Model MS-9 mass spectrometer leak detector (Vacuum Electronics Manufacturing Corporation) and spraying helium gas on the welded area after the system had been pumped down to a vacuum better than 10^{-5} mm of mercury. The leak detector had an ultimate sensitivity of 2×10^{-10} standard cc/sec. Prior to testing the aluminum cans the Veeco apparatus was checked with a sensitivity calibrator (Type SC4) which provides a helium leak rate of $3 \times 10^{-8} \pm 10\%$ standard cc/sec.

(3) Microexamination

The welded caps of one end of the aluminum can and one end of the stainless steel tube containing the cobalt core of each encapsulation were sectioned, mounted in Lucite plastic, polished and examined under the microscope. Photomicrographs were taken at a magnification of 3X.

Results of Examination After Thermal Cycling

a. Fluorescent Penetrant Test

Encapsulation A - No visible indication of defects

Encapsulation B - No visible indication of defects

b. Helium Leak Test

Encapsulation A

Top aluminum cap - No leakage
Bottom aluminum cap - No leakage

Encapsulation B

Top aluminum cap - No leakage
Bottom aluminum cap - No leakage

c. Microexamination

When examined under the microscope at magnifications up to 1000X, the micro-structures of the welded caps of the aluminum cans and the welded caps of the stainless steel tubes appeared to be consistent with sound welds with no evidence of harmful porosity or cracks. Photomicrographs at 3X magnification of one end of each of the encapsulations were obtained and are included in the official report.

Summary

Examination of the two cobalt encapsulations after thermal cycling indicated that the integrity of the welds was satisfactorily maintained. There was no other evidence of progressive deterioration resulting from the alternate differential expansion and contraction to which the encapsulations were subjected.

Post Activation Testing of Test Slugs

As discussed in an earlier portion of this section, two of the six test slugs sent to Savannah River were placed into one of the reactor cycles and irradiated, while the remaining four slugs were destructively tested. The two slugs being irradiated will be removed from the reactor in early summer, being effectively a year older than the slugs which will make up the source for the Food Process Development Irradiator. Through the monitoring and observance of these two test slugs, deficiencies or malfunctions will be noted in sufficient time to take preventive measures on the megacurie source.

A detailed program for these test slugs is currently being developed. They will be shipped to Dugway Proving Ground, Dugway, Utah, to representatives of the United States Army's Chemical Corps. The slugs will be subjected to normal operating conditions, including storage in water and exposure to air in repeated cycles similar to those to be encountered in actual use. It is contemplated that storage will be in a small pool with the water characteristics duplicating those of the actual source pools.

The slugs will be visually and microscopically inspected at regular intervals, with the results reported back to the AEC until the facility is turned over to the Quartermaster Corps, and then will be reported to the QM. A detailed and complete log will be maintained on this source during its existence.

It is anticipated that this small source, being an estimated 6,000 curies, will be utilized as a source, rather than merely be stored in a hot cell. This will further aid in assaying the quality of the source and extent of effective radiation to exposed sources.

The monitoring of these two slugs is the most positive assurance that the cobalt 60 source in the QMRL will be maintained in a trouble-free atmosphere. Through keeping a close account of what happens to them, it is anticipated that problems relating to leakage, corrosion or pitting, for instance, will be detected early, with the corresponding corrective action undertaken in the facility source.

If results of the monitoring of these two slugs should so indicate, the entire source will be re-evaluated, and reconsideration given to the proposed capsule and conditions of use. However, it is felt that positive corrective action will be sufficient to correct any possible shortcoming which may develop. It is obvious that no trouble or shortcomings of the proposed source are expected, based on current knowledge gained through the experience of others. Yet to invoke a program similar to that for the two test slugs is to provide an additional assurance of safety and confidence in the large source, with the knowledge that source technology has also been greatly advanced. For in addition to being somewhat novel in its intended use, that of radiation preservation of food, this megacurie source is also relatively novel. When completed, it will represent the largest single cobalt 60 source in the world. Its operation and functioning will undoubtedly bear as much scrutiny as the products it will be irradiating.

Operational Maintenance

Summarized in this sub-section are the more important operational and maintenance procedures which will govern activities during shipment, loading and initial operation of the cobalt source. In addition to the specific items discussed, it is the intention in the use of this source to maintain as the minimum operational specifications those as specified in Part 20 CFR.

In the discussion of the fabrication of the cobalt source, the careful handling of the slugs was stressed. During normal operation this careful handling shall continue to the extent practical. The design has been accomplished so that no extraneous rough handling of these sources will occur.

Pre-shipment Handling

After irradiation at Savannah River, the cobalt slugs will be stored in a basin until shipment. The basin water is monitored periodically, and the monitoring is sensitive enough to respond if the cladding of one of the slugs fails. The fuel rupture detection devices installed in the reactor hydraulic system are even more sensitive and if a cladding defect occurs it would be detected before the cobalt slug is placed in the storage basin.

During assay the slugs will be given a rough visual inspection. Only large dents or gouges would show up in the inspection and it cannot be guaranteed that the outer aluminum jacket will be intact on shipment. However, SROO feels certain that if both the aluminum and stainless steel cans on one slug are ruptured it will be detected prior to shipment.

Monitoring of Water in Cask Shipping

It is proposed that the SRP shipping cask be thoroughly washed and rinsed before use. It should then be filled with demineralized water and allowed to stand for several days, after which it should be sampled and radioassay made of the sample to determine if any appreciable activity is being picked up from the shipping cask itself.

After loading of the slugs into the cask, both the internal and the external portions of the cask should be thoroughly flushed to remove any radioactivity picked up from the canal operations. The cask should then be drained and filled with demineralized water and let stand for a period of about a week before shipment. During this period, water samples should be taken for radioassay. The rate of build-up of activity in the water should be plotted and the measured rate compared to a predicted rate based on corrosion of the aluminum jackets. If unexpectedly high radioassays are obtained for the water samples, the situation should be investigated further, possibly including the determination of specific radioisotopes such as Zn-65 and Co-60 that could give evidence on the source of the activity. Since it is planned to ship two casks at a time, the rate of build-up activity in both casks should be compared, and if similar results are not obtained the situation should be investigated further.

The temperature of the water in the cask will not exceed 90°C during transit. The central metal temperature of the cobalt slugs will be somewhat higher, but considerably lower than the temperatures experienced during irradiation. Temperatures in this range should not create thermal stress problems.

On receipt of the shipping casks at the Quartermaster Research and Engineering Center, water samples should again be collected and radioassayed. The activity levels obtained should be compared with those that would be predicted from the rate of build-up found before shipment. If the results do not look reasonable, the situation should be investigated more carefully. If the activity levels are found to be as expected, the casks can be lowered into the pool with the shipping water in place, provided the activity level is reasonably low. If the activity level is fairly high, it might prove desirable to collect this activity before introducing the cask to the pool. This could be done by recirculating the cask water through a demineralizer bed or by draining it into drums for temporary storage and eventual disposal.

The radioassay of the water samples should be done by evaporating the sample, transferring the residue to a planchet which is then counted. Distinction should be made between gross beta and gross gamma counts. If the activity levels were found to be high and it was desired to determine whether cobalt corrosion was taking place, it would be possible to distinguish between specific isotopes, such as Co-60 and Zn-65, by gamma ray spectrometer measurements. All planchets used for counting should be preserved so that they will be available in the event that more refined counting measures are required.

Cask and Slug Handling

The slug shipping cask will be received at QMRL at the cask pool outside of the gamma cell. Cask water will be checked for activity, as described above, and the outside of the cask will be washed to remove all road grime.

Nuts on the cover bolts will be removed and cables attached to the cask body and the cask top. The cask will be lowered to the bottom of the pool by a yard crane, taking care that the cover cable will be slack. When positioned at the bottom, the cover will be lifted off and removed from the pool by the yard crane. The slug tote-baskets will be grappled and removed from the cask. At this point, the cask may be removed from the pool. Individual slugs will then be removed from the baskets and placed on a small inspection table for macroscopic inspection using 15 power binoculars, which will make the slugs appear to be about 2' from the observer. The operator will work from a portable platform during these source manipulations. This platform is a walkway with hand rails which is manually moved about and located at any desired angle across the pool opening. When in place, it will be pinned by suitable means to the curb around the pool top. A slug handling tool will be provided (one for each pool) which will handle slugs in a vertical position. The same tool (or another if required) will be capable of handling slugs in a horizontal position. A tilting device described below will return horizontal slugs to a vertical position.

After inspection, slugs will be placed in a stainless steel jacket for transfer into the gamma pool. This jacket is used to protect the aluminum cladding. The slug, in its jacket, will then be raised to the opening of the inclined transfer chutes. The incline angle is 27° from the horizontal. Here they will be inserted into a device which is capable of tilting the source and its jacket into the mouth of the tube. It will slide by gravity down the length of the tube and into a tilting receiving device near the bottom of the gamma pool. The tilting device acts as a dash-pot for decelerating the slug. It also returns the slug to a vertical position for handling by the source tool. This device is also used to return horizontal slugs to a vertical position.

The slug is removed from the jacket vertically and transferred to the slug racks. Here they are inserted into the wide mouth source holding tubes. The transfer jacket is returned to the cask pool for re-use.

When all of the slugs have been received, an arrangement plan will be worked out to attain uniformity of activity throughout the source slabs.

Slugs will be removed from the storage racks and inserted into the source holding tubes by the same handling tool. These tubes and their mandrils are shown in figure 3-2. Individual slugs will be identified by their code numbers which can be seen through the binoculars.

Four slugs are placed into one tube, making a slab subassembly. Another tool will pick up tubes for insertion over mandrils on the elevator jig plates.

Manipulations of the sources in the gamma pool are carried out by an operator standing on a portable walkway, similar to that used for the cask pool. This walkway is manually placed along the predetermined line of source movement and pinned to the floor at the pool edges.

In addition to the source tube tool, a general purpose pick-up hand will be supplied. A general purpose tool will also be supplied with a screw type end fitting into which hooks, wrenches, and miscellaneous tools may be fitted.

The source elevator will be as shown on the Curtiss-Wright design drawings. The general arrangement is shown in figure 3-28. The testing of the assembled elevator will be more fully described in Part II, Facility Description. This procedure will differ only in the detailed operations which were peculiar to the HIFI elevator design.

Pool Water Sampling

During the first year of operation, the pool water should be sampled for the following determinations:

A. Radioassay

1. Gross beta* and gross gamma*

2. Zinc 65*

3. Cobalt-60 (None normally present)

* For normal expected activity levels, see Curtiss-Wright final report.

B. Chemical

1. pH (normally 7)

2. Electrical Conductivity (Normally approximately 500,000 ohms)

3. Chloride Content (normally less than 1 ppm)

The samples should be taken approximately once a week and the radioassay work can be done in the Quartermaster Radiation Laboratory; the chemical determinations can be made in the Chemistry Laboratory elsewhere at the Research and Engineering Center. Monthly determination of the Zn-65 and Co-60 would probably be adequate since any marked changes should be indicated by the weekly gross beta and gross gamma levels, as well as the continuous ion exchange column monitoring.

Ion Exchange Column Monitoring

A radiation monitor will be provided for the ion exchange column to measure the gamma radiation emitted from radioisotopes absorbed on the column resins. The monitor will be arranged so that it can be moved along the side of the column to be positioned at the point of maximum radiation as the absorption front moves through the bed. The monitor will probably be of the Victoreen type and will have a three decade range going from .01 mr/hr to 10 mr/hr. The radiation level will be indicated and recorded at the cobalt-60 control panel. An adjustable high level alarm will be provided that will give the operator warning in the event of a sudden rise in the radiation level.

In addition to the permanently installed monitor, it will be possible to obtain additional information on the activity in the deionizer by the use of portable survey instruments.

Air Sampling, Including Filter System

The design presently calls for the installation of absolute filters on the exhaust cobalt-60 cell which will prevent the escape of any radioactive aerosols in the extremely unlikely event that any of these ever entered the ventilation air stream. In addition, it is planned to install a Victoreen type remote monitor at these filters to determine the radiation level on the filters. This instrument will be sensitive to gamma radiation and will have a range of 0.01 mr/hr to 10 mr/hr, and will be provided with an adjustable high level alarm.

In addition to this permanently installed equipment, air sampling will be performed as part of the normal health physics survey duties. A high volume air sampler will be provided and aerosols will be collected through high efficiency filter papers which will then be counted. This air sampling would include all of the work areas within the Laboratory, as well as the cobalt cell itself, and the air downstream of the absolute filters being discharged to the stack. The filter papers will be counted in the radiation laboratory to determine activity levels.

Underwater Microscopic Source Examination

No plans are being made at present for any underwater microscopic examination of the source slugs. This is being done on the basis that any macroscopic change in the physical makeup of the slugs will reveal its presence by virtue of changes of the radioactive content of the water. In the event that changes are found in the radioactive levels of the pool water, the failed slugs can be isolated by virtue of the radioactivity they are putting into the pool water. This would be done by placing each of the slugs, in turn, into a tube connected to the recirculating pump suction and the damaged slugs determined by an increase in the activity of the deionizer bed.

This proposed method of procedure is in keeping with the common practice wherein MTR fuel elements have been used in gamma irradiation pools. In these instances, we know of no underwater microscopic source examinations that were undertaken. Our position then is that these examinations should be deferred until there is some indication that they are needed and will serve some purpose.

Other Monitoring and Safety Checks

It is planned to have two methods of remote observation within the radiation cell, consisting of a television system and an optical system. These observation systems are primarily intended as safety devices and would come into play mainly in the event of trouble within the cell when the radiation sources were in the raised condition. Two systems are being included which are as unalike as possible to lessen the chance of both of them becoming simultaneously unavailable for use in an emergency.

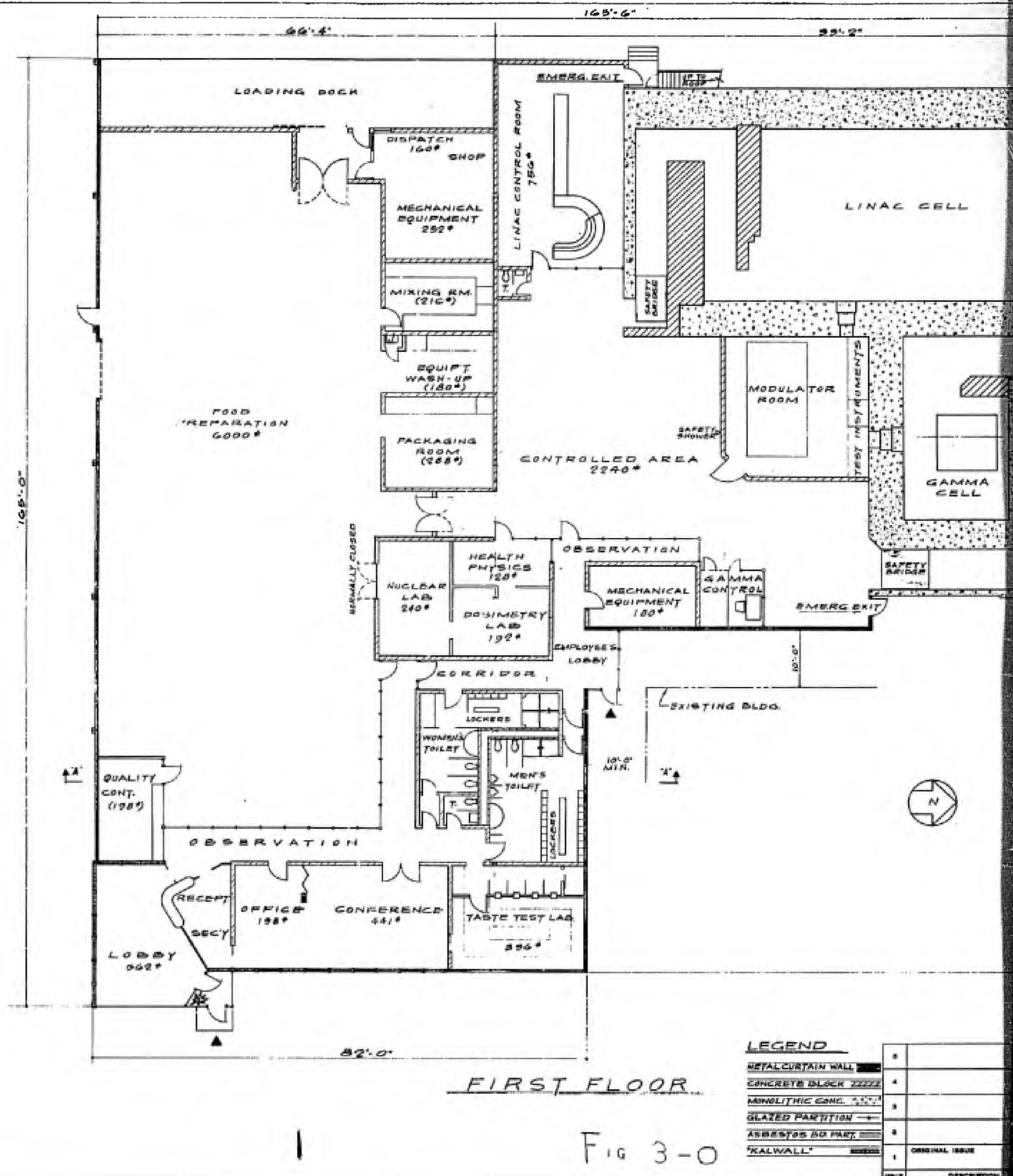
In addition, a man-trap is being provided with a cell lockup and unlocking procedure. The present design calls for a provision of a pressure plate in front of the man-trap to guard against persons accidently falling into the man-trap. In addition, it is contemplated that the man-trap will be provided with a net which will minimize physical injury in the event that someone falls into it.

VII. CONCLUSION

The data presented in this Part have related primarily to the megacurie cobalt 60 source and source handling equipment for the Food Process Development Irradiator. The concepts and design of this portion of the Quartermaster Radiation Laboratory have been discussed in detail.

In presenting that material appropriate and pertinent for a proper evaluation of this source, it was necessary to make a distinction between the various subjects which could have been discussed. For instance, the production of ozone by the cobalt 60 certainly is a source characteristic, yet more properly falls within the category of ventilation requirements. Similarly, an account of standard operating procedures in the use of the source, including the various safety devices to prevent unauthorized entry of personnel into the source cell would be related to this account indirectly, but would not necessarily be a requisite to the evaluation of the source. This account, therefore, was limited to those areas which would have a direct effect in some way on the operation, safety, and maintenance of the FPDI cobalt 60 source.

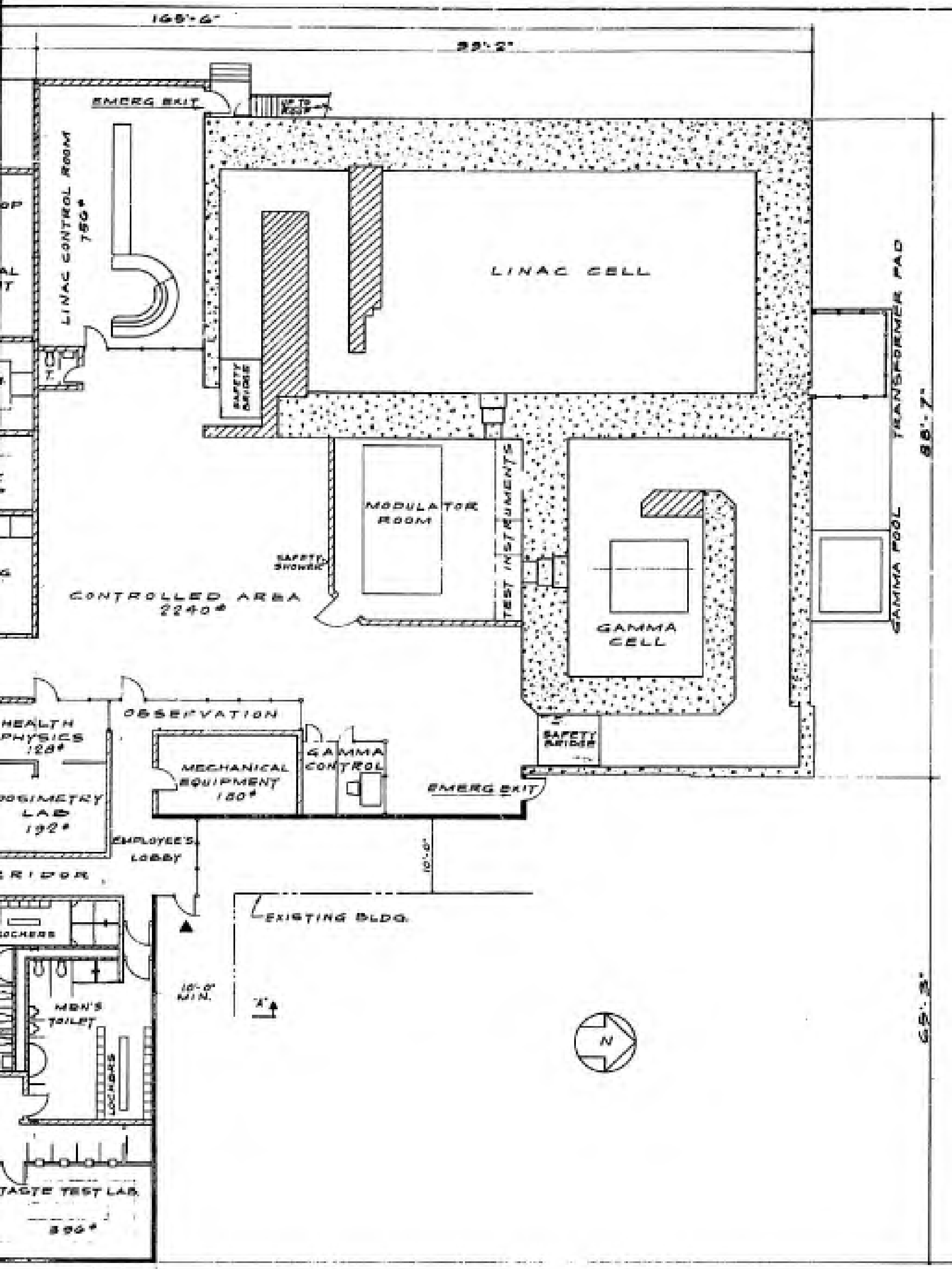
A final point is worthy of reiteration: a portion of the material on which the successful operation of this source is predicated is theoretical in nature. The greatest assurance of source integrity and safety lies in the physical monitoring of the test slugs which will be over a year older than the production cobalt 60. If experience during the monitoring of these two test capsules, or with a related source used by some other group should prompt reconsideration of the proposed capsule and its conditions of use, then such reconsideration will be given.

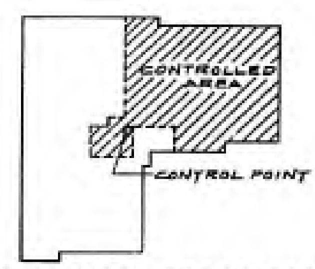


FIRST FLOOR

1

FIG 3-0





CONTROL DIAGRAM

FIRST FLOOR

LEGEND

METAL CURTAIN WALL	
CONCRETE BLOCK	
MONOLITHIC CONC.	
GLAZED PARTITION	
ASBESTOS BD. PART.	
"KALWALL"	

ISSUE	DESCRIPTION	CHKD.	INSP.	CORR.	APPR.
5					
4					
3					
2					
1	ORIGINAL ISSUE				

ARCHITECTURAL FLOOR PLAN

QUARTERMASTER RADIATION LABORATORY
FOR
U. S. ATOMIC ENERGY COMMISSION
ASSOCIATED NUCLEONICS, INC.
A SUBSIDIARY OF
STONE & WEBSTER ENGINEERING CORPORATION

2

DRAWING NUMBER

FIG 3-O

DO NOT SCALE
BREAK ALL SHARP EDGES

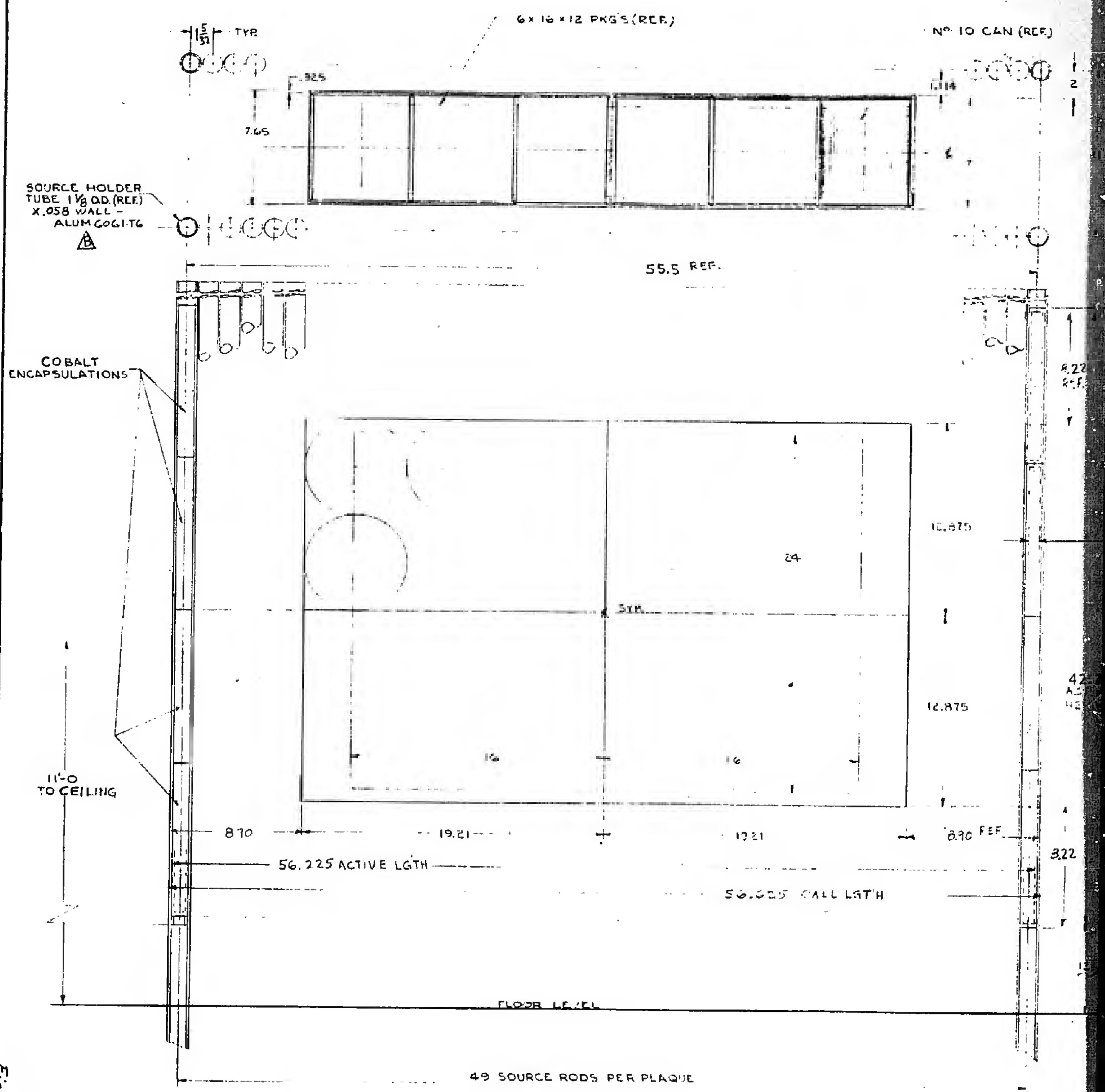
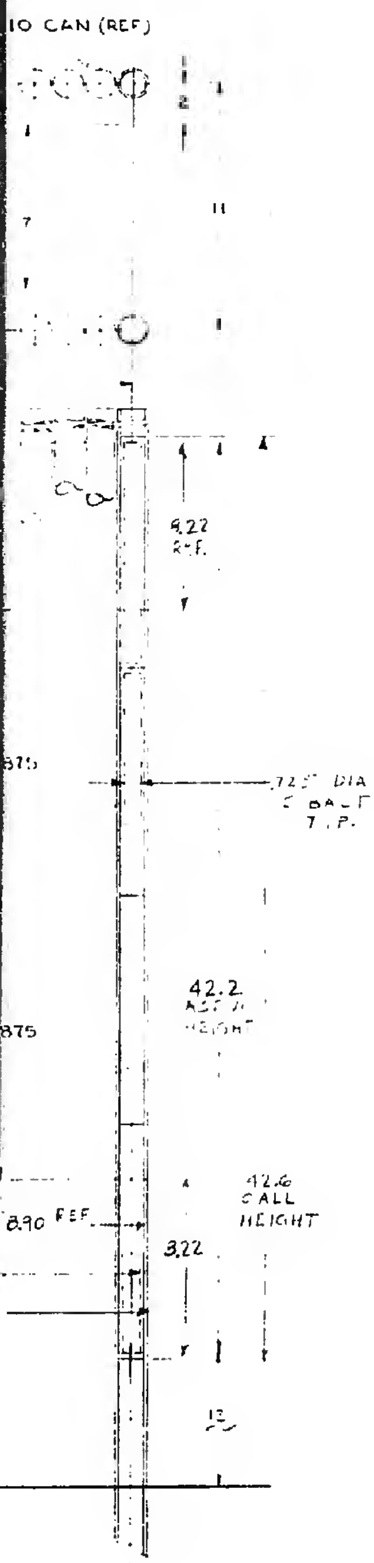


Fig 3-7.

REVISIONS			
SYM.	DESCRIPTION	DATE	APPROVAL
A	42.6 WAS 41.615 ... 15/64 WAS 1 1/8, 55.5 WAS 54 ADDED 56.225, 56.615, 8.90, 3.22 1.114 WAS 1.14 - ADDED .725 D. & 42.2	11-27	
B	[illegible]		



D-700323

B

DET.	PART NO	REQ'D	DESCRIPTION	MAT'L & SIZE	MAT'L SPEC.

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACT ± 1/64 CASTING ± 1/16
DECIMAL ± .005 FORGING ± 1/16
ANGULAR ± 1°
SPECIFICATION:
HEAT TREAT:
FINISH:

DRAWN / CHECKED / APP'VD / ENG APP'L — NAME / DATE

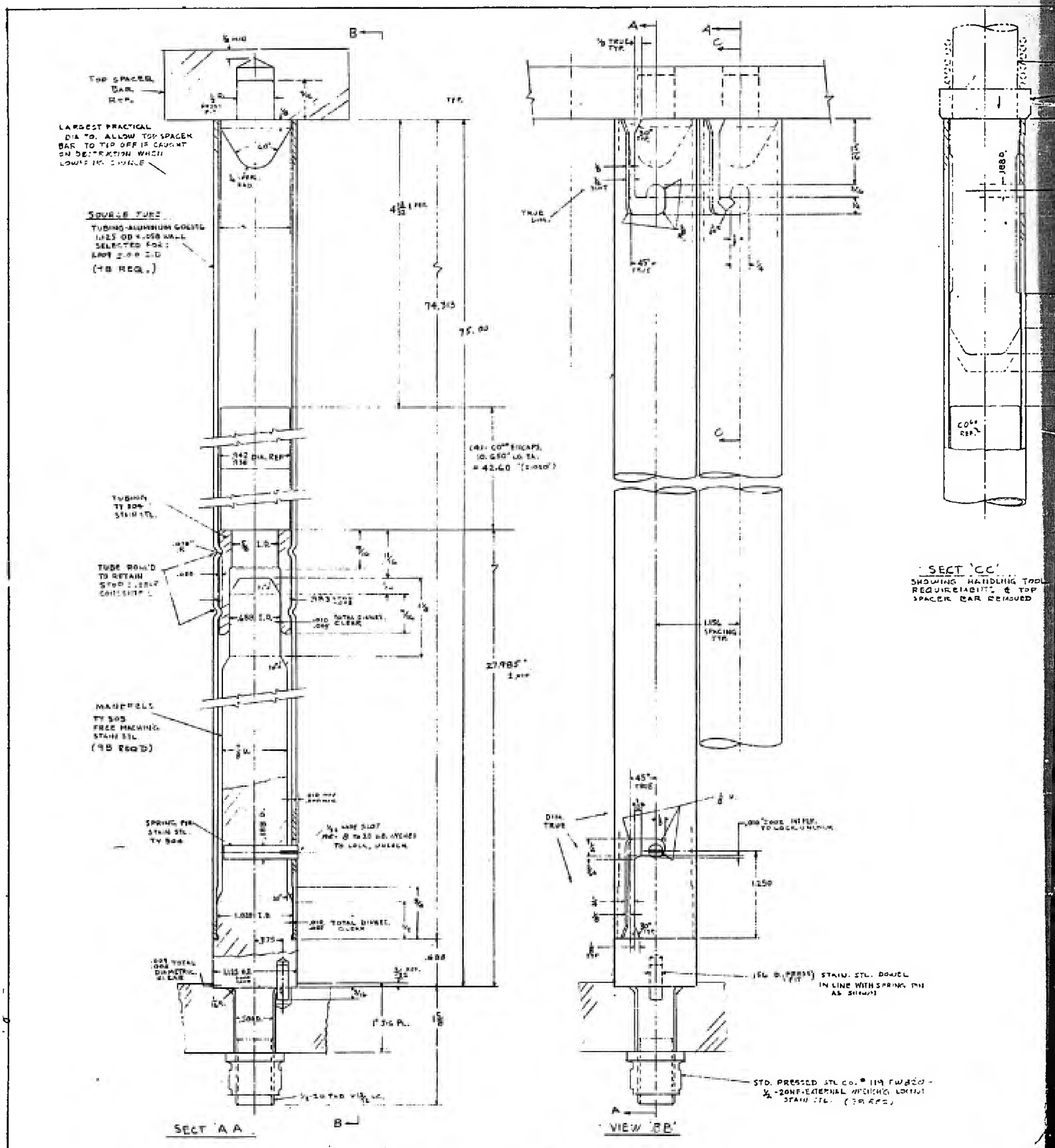
TITLE:
F. R. D. I.
RELATIONSHIP OF
PACKAGE TO SOURCE
(SINGLE PASS)

SCALE

Fig 3-1.

CURTISS-WRIGHT CORP.
PRINCETON DIVISION
PRINCETON, NEW JERSEY

D-700323 B



TOP SPACER BAR REF.
LARGEST PRACTICAL DIA TO. ALLOW TOP SPACER BAR TO TIP OFF IF CAUGHT ON DESTRUCTION WHICH LOWERS IN SPACE
DOUBLE TUBE
TUBING-ALUMINUM
(48 REQ.)
TUBING TY 304 STAIN STL.
TUBE ROLL'D TO RETAIN
MANDRELS
TY 303 FREE MACHINING STAIN STL.
(98 REQ'D)
SPRING PIN STAIN STL. TY 304
74.313
75.00
27.985"
42.60
TOTAL DIAMET. CLEAR
1.250
1.036 I.D.
.375
.688
1 5/8
1/2-20 THD
1.050 SPACING TYP.
TRUE DIA.
45°
STAIN. STL. DOWEL IN LINE WITH SPRING PIN AS SHOWN
STD. PRESSED STL CO. # 119 FW820 - 1/2 -20NF-EXTERNAL
SECT 'AA'
VIEW 'BB'
SECT 'CC'
SHOWING HANDLING TOOL REQUIREMENTS & TOP SPACER BAR REMOVED
.188

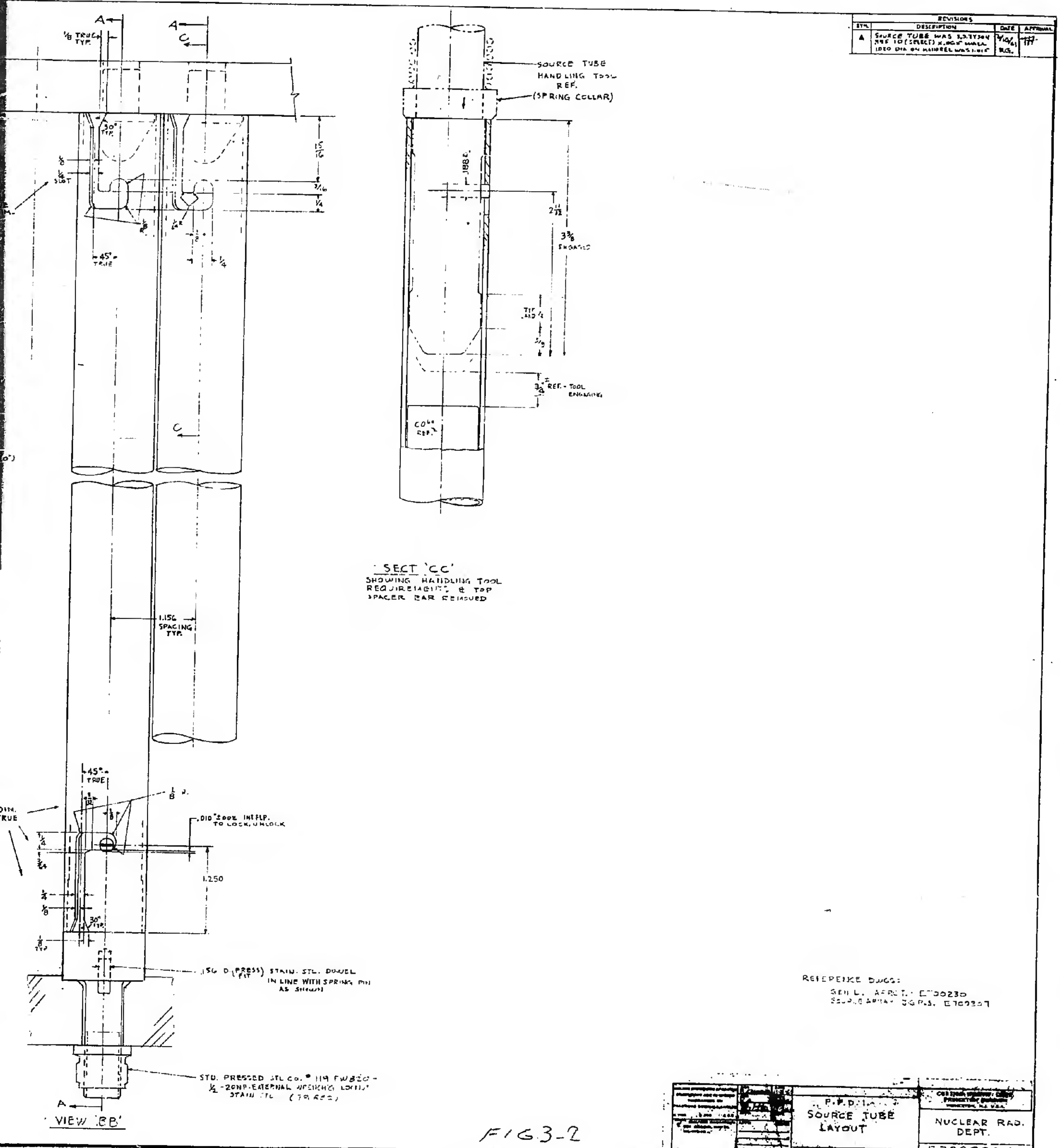
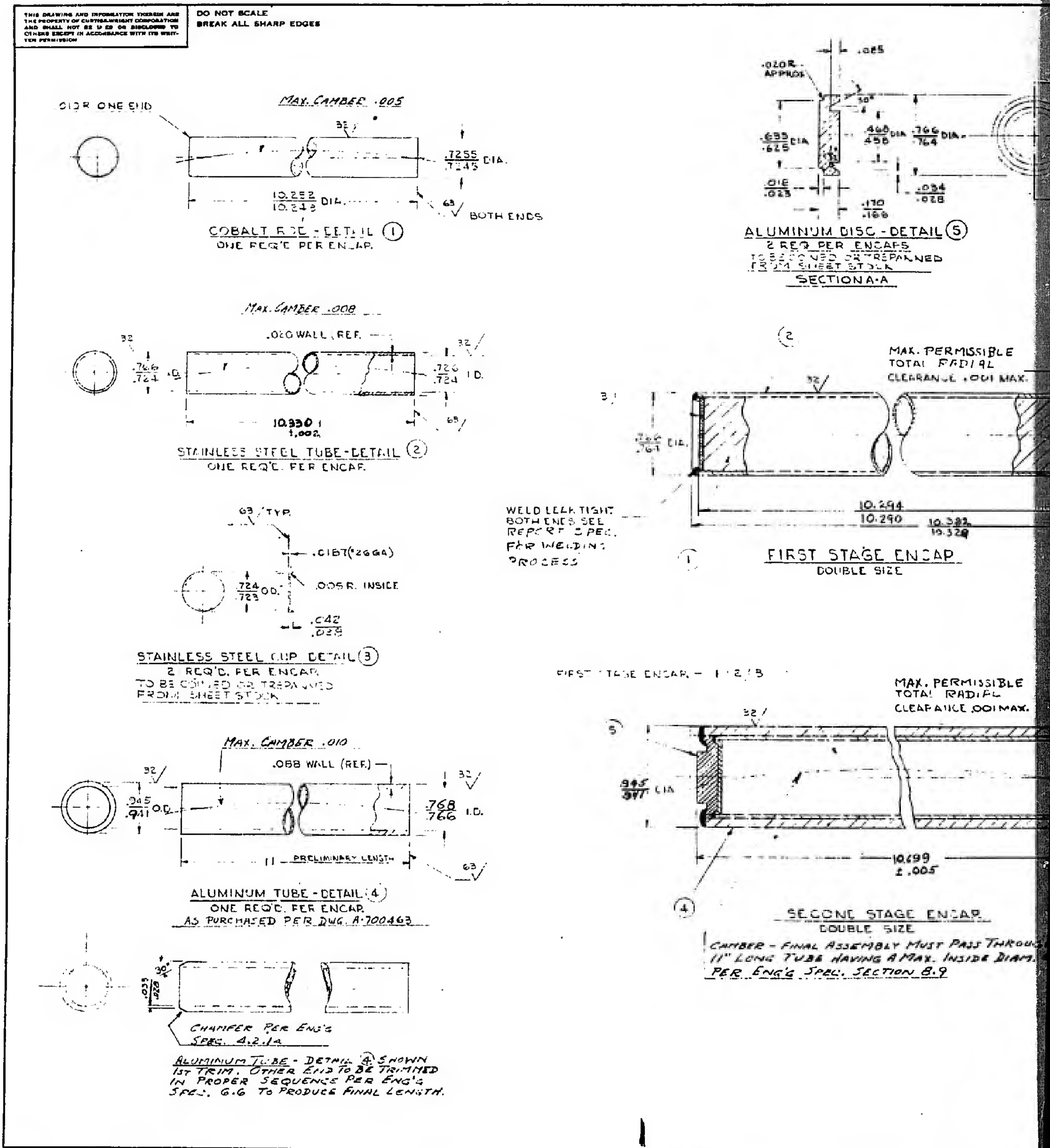
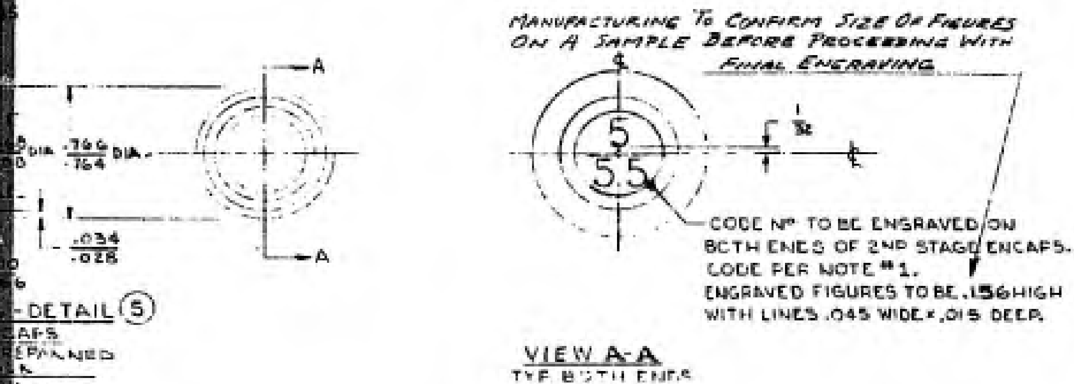

REVISIONS
SOURCE TUBE HANDLING TOOL REF.
(SPRING COLLAR)
SECT 'CC'
SHOWING HANDLING TOOL REQUIREMENTS & TOP SPACER BAR REMOVED
1.156 SPACING TYP.
1.250
.156 D (PRESS FIT) STAIN. STL. DOWEL IN LINE WITH SPRING PIN AS SHOWN
STD. PRESSED STL. CO. # 119 FWB20 - ½ - 20NP EXTERNAL WRENCHING LOCK STAIN. STL. (79 REQ)
VIEW 'BB'
REFERENCE DWGS:
SOURCE TUBE LAYOUT
NUCLEAR RAD. DEPT.
E700290 A

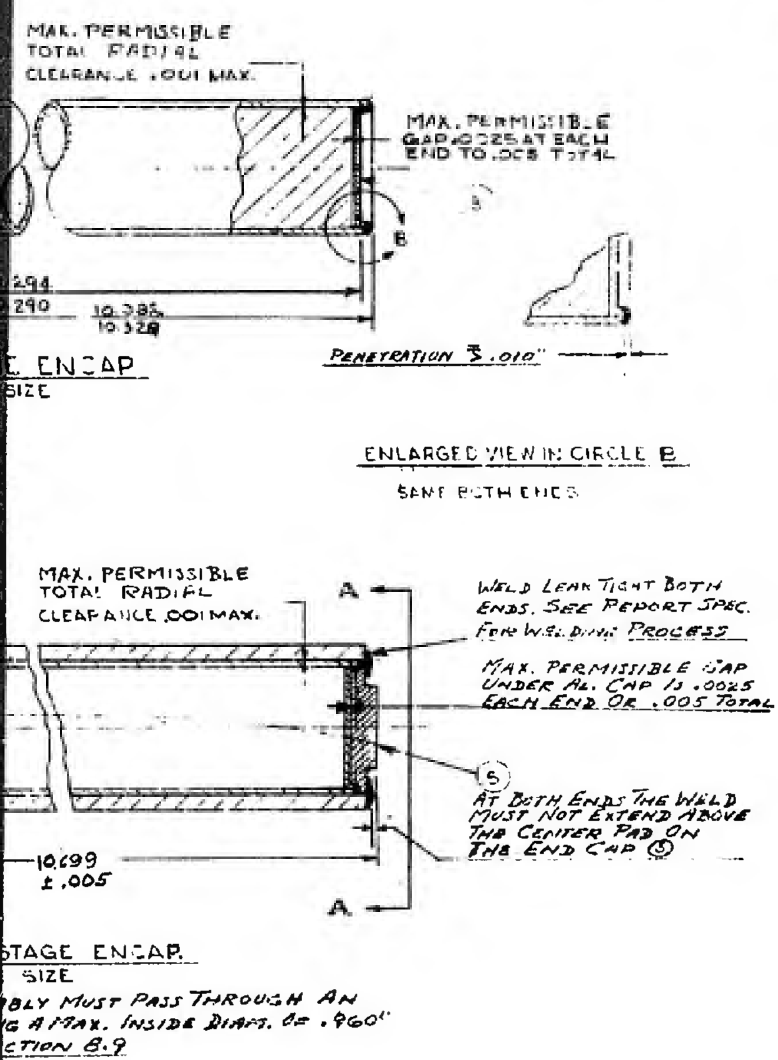
FIG 3-2



THIS DRAWING AND INFORMATION THEREIN ARE THE PROPERTY OF CURTISS-WRIGHT CORPORATION AND SHALL NOT BE USED OR DISCLOSED TO OTHERS EXCEPT IN ACCORDANCE WITH ITS WRITTEN PERMISSION
DO NOT SCALE
BREAK ALL SHARP EDGES
MAX. CAMBER .005
BOTH ENDS
COBALT ROD - DETAIL (1)
ONE REQ'D PER ENCAP.
MAX. CAMBER .008
.020 WALL (REF.
STAINLESS STEEL TUBE-DETAIL (2)
ONE REQ'D. PER ENCAP.
.005 R. INSIDE
STAINLESS STEEL CUP DETAIL (3)
2 REQ'D. PER ENCAP.
MAX. CAMBER .010
.088 WALL (REF.)
PRELIMINARY LENGTH
ALUMINUM TUBE - DETAIL (4)
ONE REQ'D. PER ENCAP.
AS PURCHASED PER DWG. A-700463
CHAMFER PER ENG'G SPEC. 4.2.1a
ALUMINUM TUBE - DETAIL (4) SHOWN 1ST TRIM. OTHER END TO BE TRIMMED IN PROPER SEQUENCE PER ENG'G SPEC. 6.6 TO PRODUCE FINAL LENGTH.
ALUMINUM DISC - DETAIL (5)
2 REQ PER ENCAPS
SECTION A-A
MAX. PERMISSIBLE TOTAL RADIAL CLEARANCE .001 MAX.
WELD LEAK TIGHT BOTH ENDS SEE REPORT SPEC. FOR WELDING PROCESS
FIRST STAGE ENCAP
DOUBLE SIZE
SECOND STAGE ENCAP
DOUBLE SIZE
CAMBER - FINAL ASSEMBLY MUST PASS THROUGH 11" LONG TUBE HAVING A MAX. INSIDE DIAM. PER ENG'G SPEC. SECTION 8.9

SYM.	REVISIONS DESCRIPTION	DATE	APPROVAL
E	REVISED & REDRAWN SUPERSEDES D700129-D		
F	GENERAL REVISION	2-15-61	





NOTES:

1. ENGRAVE BOTH ENDS OF 2ND STAGE WITH CODE NUMBERS AS FOLLOWS:
   - 1ST 100 ASSYS - (1/01) TO (1/00)
   - 2ND 100 ASSYS - (2/01) TO (2/00)
   - 3RD 100 ASSYS - (3/01) TO (3/00)
   - 4TH 100 ASSYS - (4/01) TO (4/00) AND ETC.
2. ASSEMBLE PER ENG. DEPT. PROCEDURE SPEC.
3. MUST PASS LEAK TEST REQUIREMENTS AS OUTLINED IN ENG'G REPORT SPECIFICATION IN SECTION 8.7
4. REFER TO INDIVIDUAL DETAILS IN ENG'G SPECIFICATION

D700129

E

DET.	PART NO.	REQ'D	DESCRIPTION	MAT'L & SIZE	MAT'L SPEC.
5	A-700398	2	2ND STAGE END CAP	3245 ALUMINUM ALLOY ZINC NOT TO EXCEED 0.1% MAX.	
4	A-700397	1	2ND STAGE TUBE	3245 ALUMINUM ALLOY ZINC NOT TO EXCEED 0.1% MAX.	
3	A-700395	2	1ST STAGE END CUP	18/8 (304) STN. ST.	
2	A-700394	1	1ST STAGE TUBE	18×8 (304) STN. ST.	REDRAW TO PRECISION SIZED
1	A-700393	1	CORE	COBALT	REACTOR GRADE

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACT. ± 1/64 CASTING ± 1/16
DECIMAL ± .005 FORGING ± 1/16
ANGULAR ± 1°

SPECIFICATION: SEE COBALT ENCAPSULATION REPORT [redacted] AND ENG'G SPECIFICATION [redacted]: OF JAN. 23-1961

	NAME	DATE
DRAWN	JFK	10-24-60
CHECKED		
APP'D		11-1-
ENG. APPL.		11/2/60
N.R.		

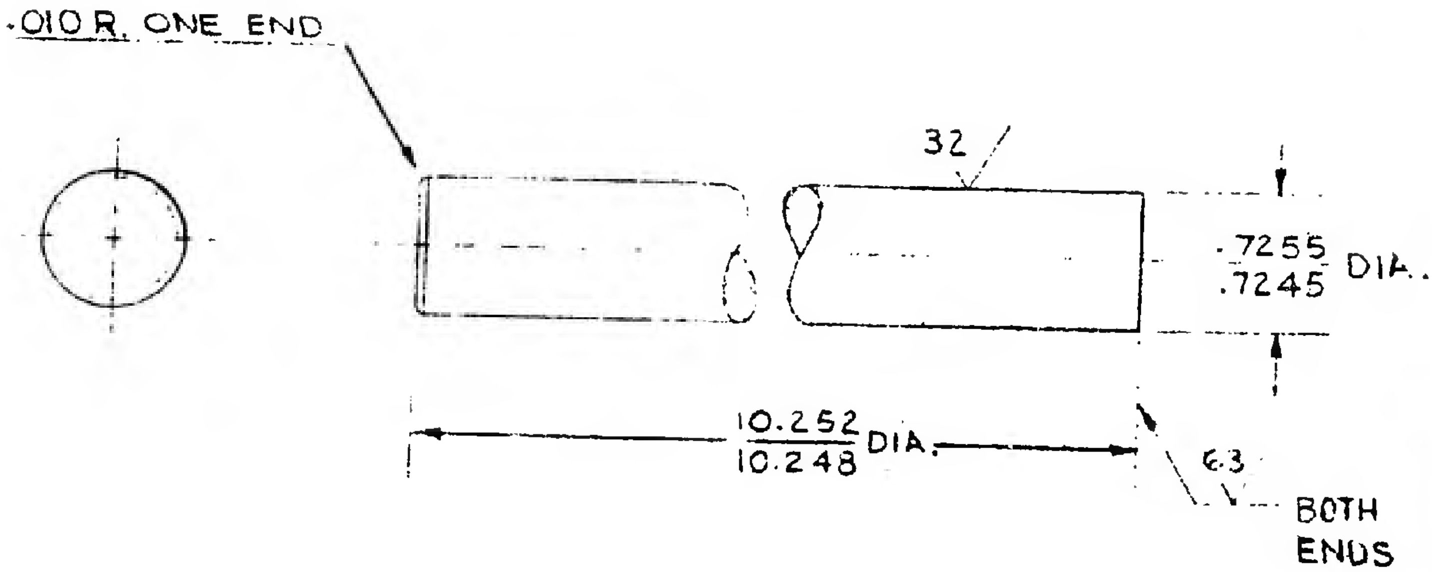
TITLE: F. P. D. I. COBALT ENCAPSULATION

SCALE — Fig 3-3

CURTISS-WRIGHT CORP.
PRINCETON DIVISION
PRINCETON, NEW JERSEY

D700129-F

2



MAT'L Reactor grade cobalt centerless ground on diameter and flat ground both ends.

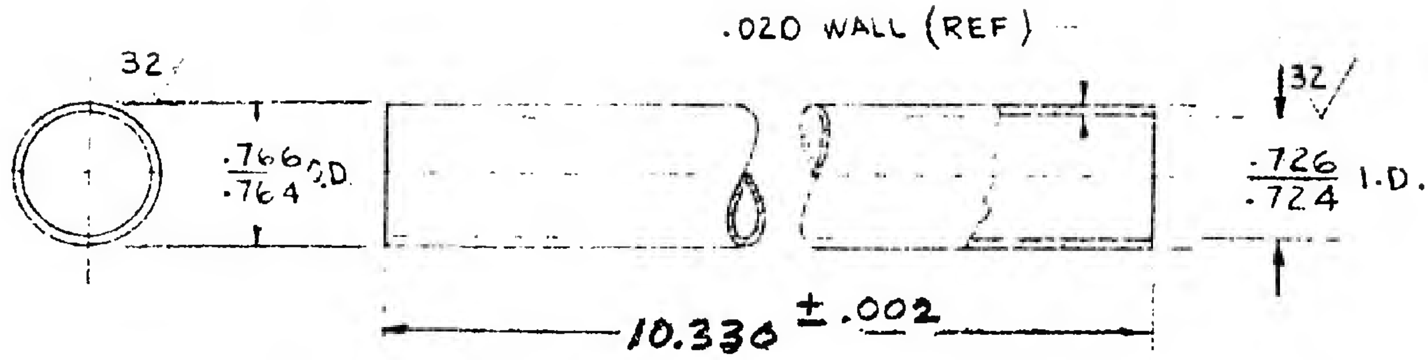
Straightness - .005"/piece (CAMBER)

CURTISS-WRIGHT CORPORATION
Princeton, N. J.

COBALT ROD
Drawing A-700393

Section 9.1 12/21/60

Fig 3-4



MAT'L 18% Cr, 8% Ni 302

stainless steel tube redrawn

to precision size shown.

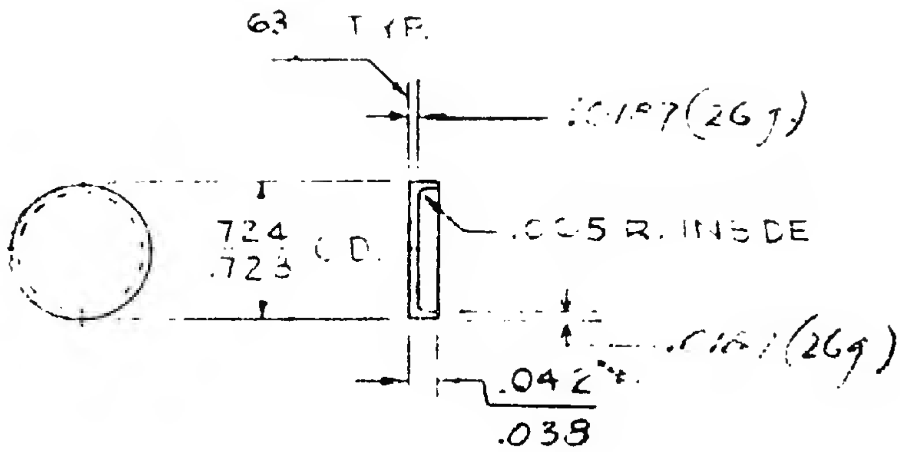
Straightness - .008"/piece (CAMBER)

CURTISS-WRIGHT CORPORATION
Princeton, N. J.

STAINLESS STEEL TUBE
Drawing A-700394

Section 9.2 12/21/60

Fig 3-5



MAT'L 18% Cr - 8% Ni 304

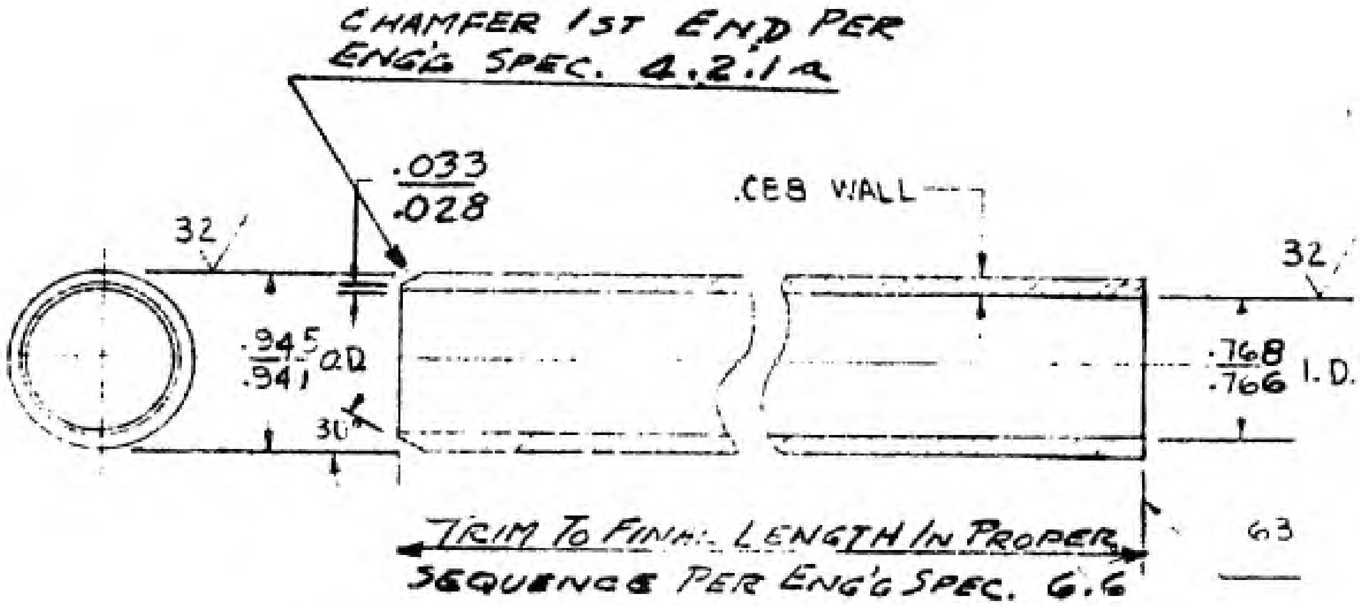
Stainless Steel Sheet.

CURTISS-WRIGHT CORPORATION
Princeton, N. J.

STAINLESS STEEL END CAP
Drawing A-700395

Section 9.3 12/21/60

Fig 3-6



MAT'L Alcoa Alloy 1245 tube
redrawn to precision size.

STRAIGHTNESS - .010" CAMBER

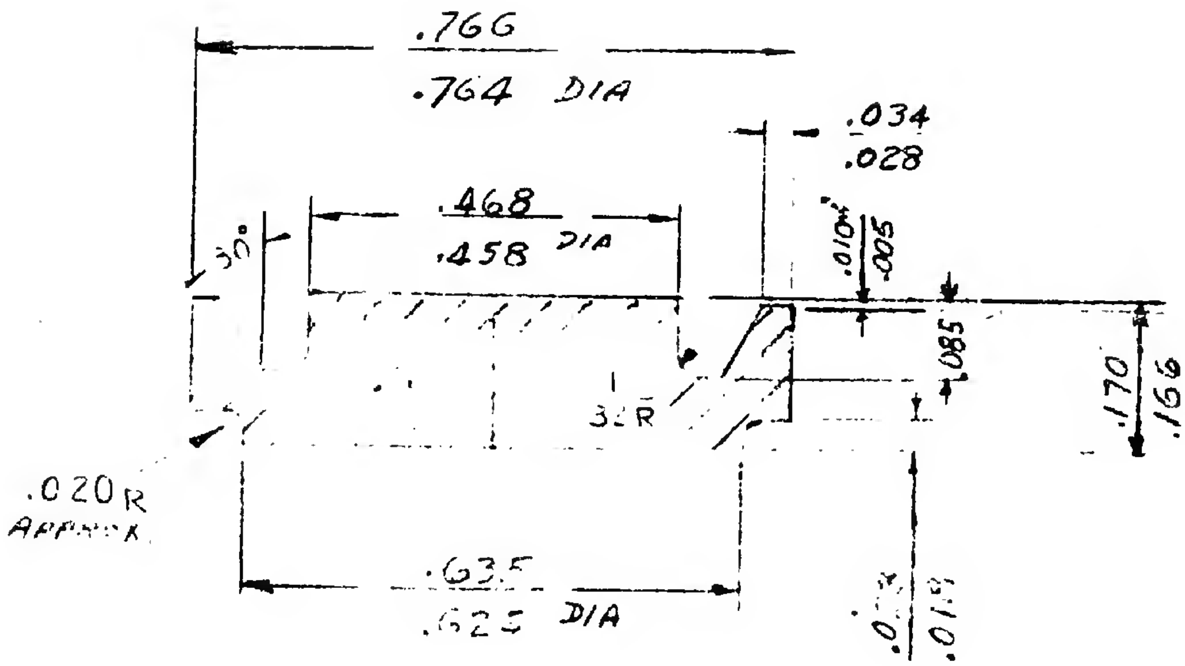
PURCHASE PER A-700463

CURTISS-WRIGHT CORPORATION
Princeton, N. J.

ALUMINUM TUBE
Drawing A-700397

Section 9.5 12/21/60

Fig 3-7



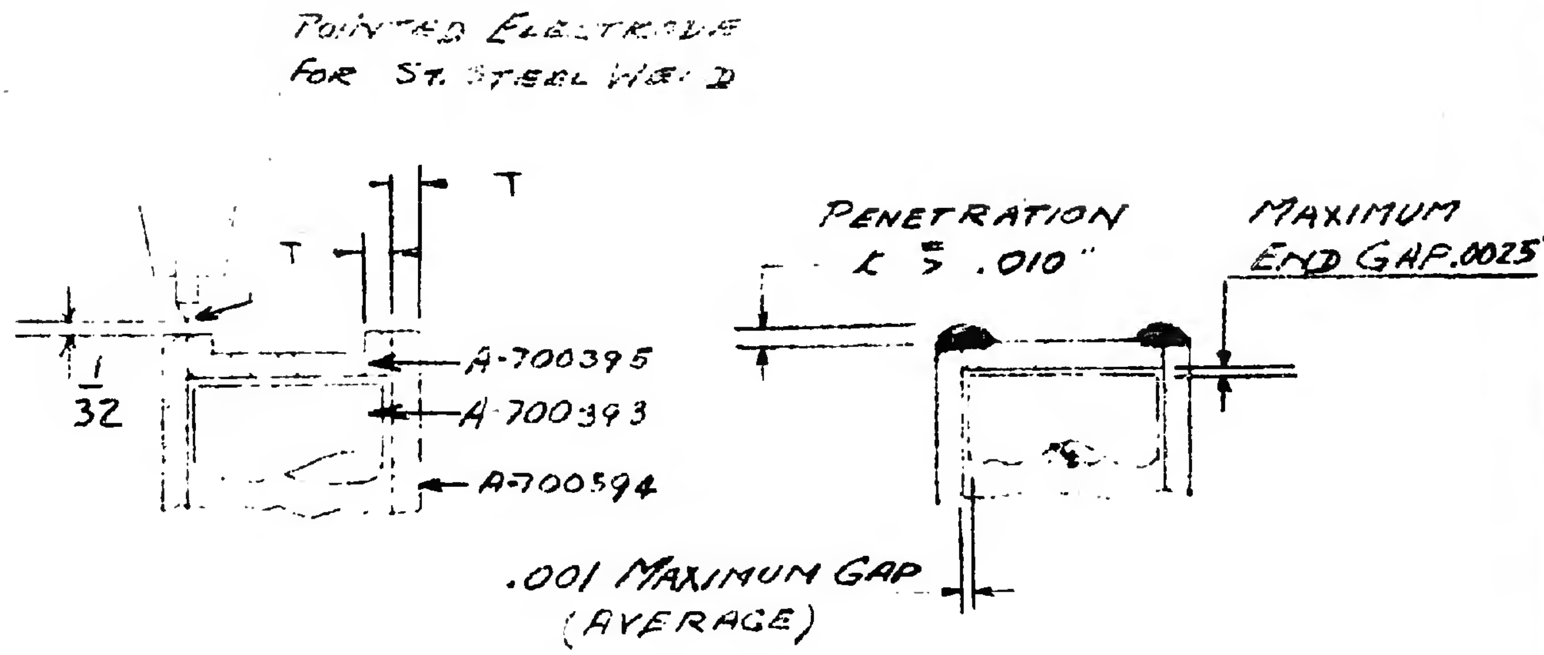
·MAT'L AlcoaAlloy - 1245

CURTISS-WRIGHT CORPORATION
Princeton, N. J.

ALUMINUM END CAP
Drawing A-700398

Section 9.6 12/21/60

Fig 3-8



Before Welding

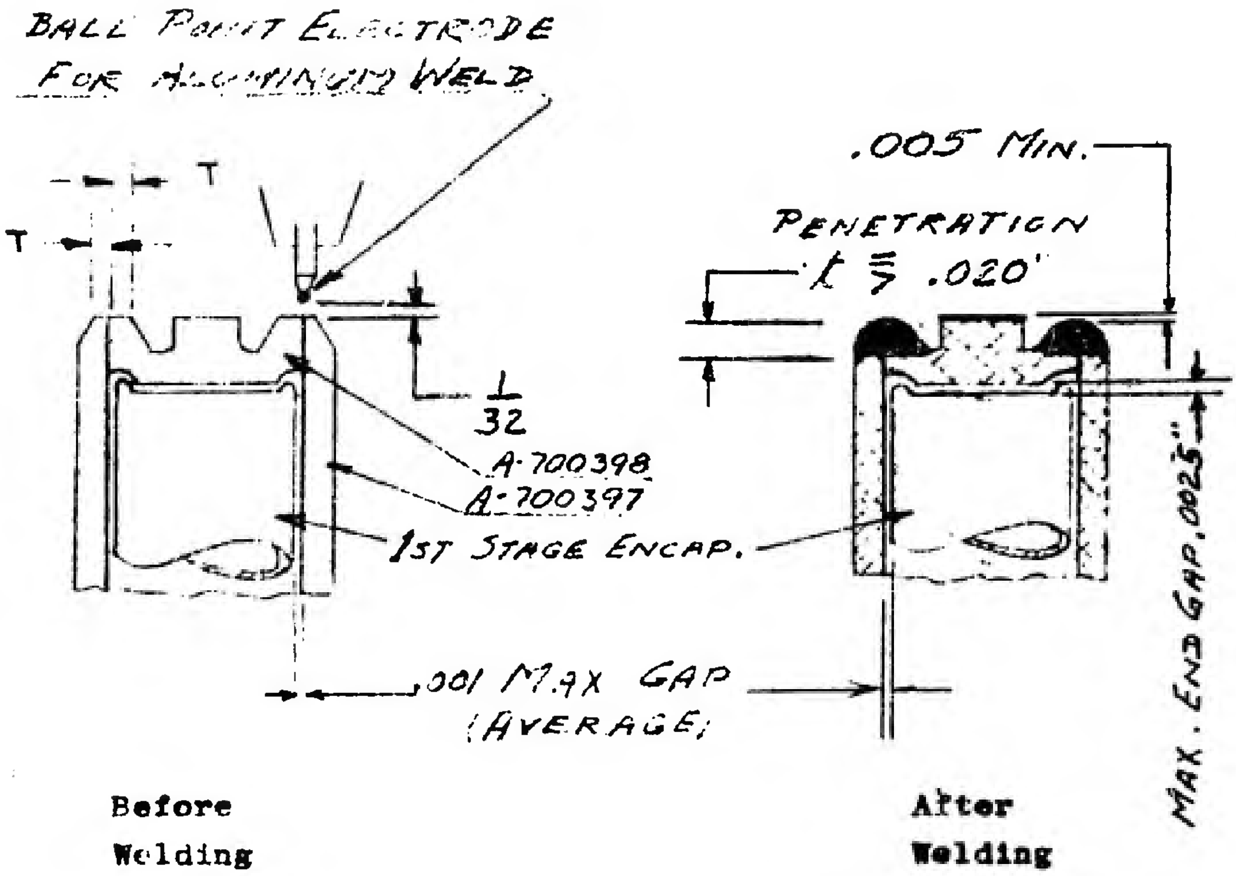
After Welding

CURTISS-WRIGHT CORPORATION
Princeton, N. J.

1ST STAGE ENCAPSULATION
Drawing A-700396

Section 9.4 . 12/21/60

Fig 3-9

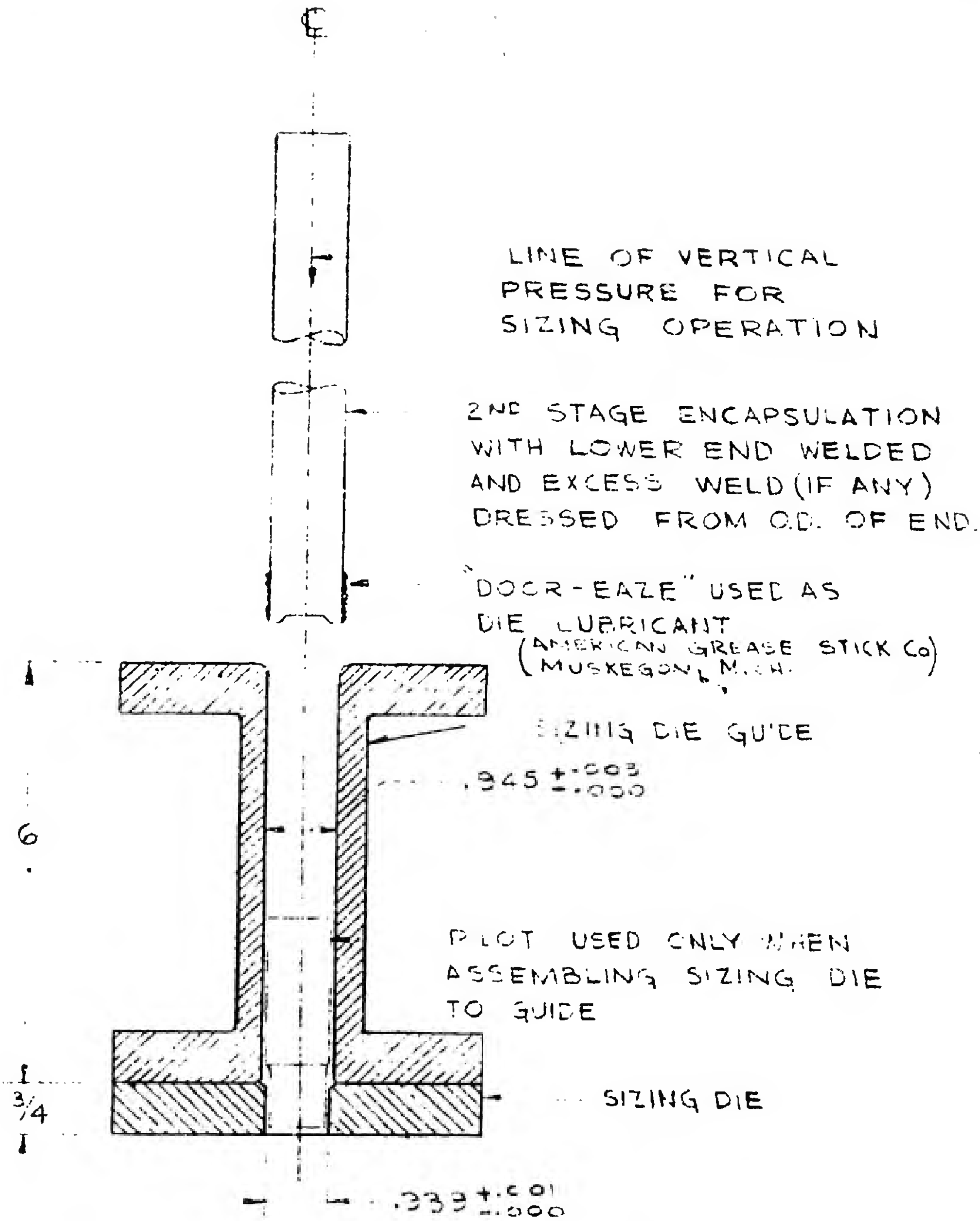


CURTISS-WRIGHT CORPORATION
Princeton, N. J.

2ND STAGE ENCAPSULATION
Drawing A-700399

Section 9.7 12/21/60

Fig 3-10



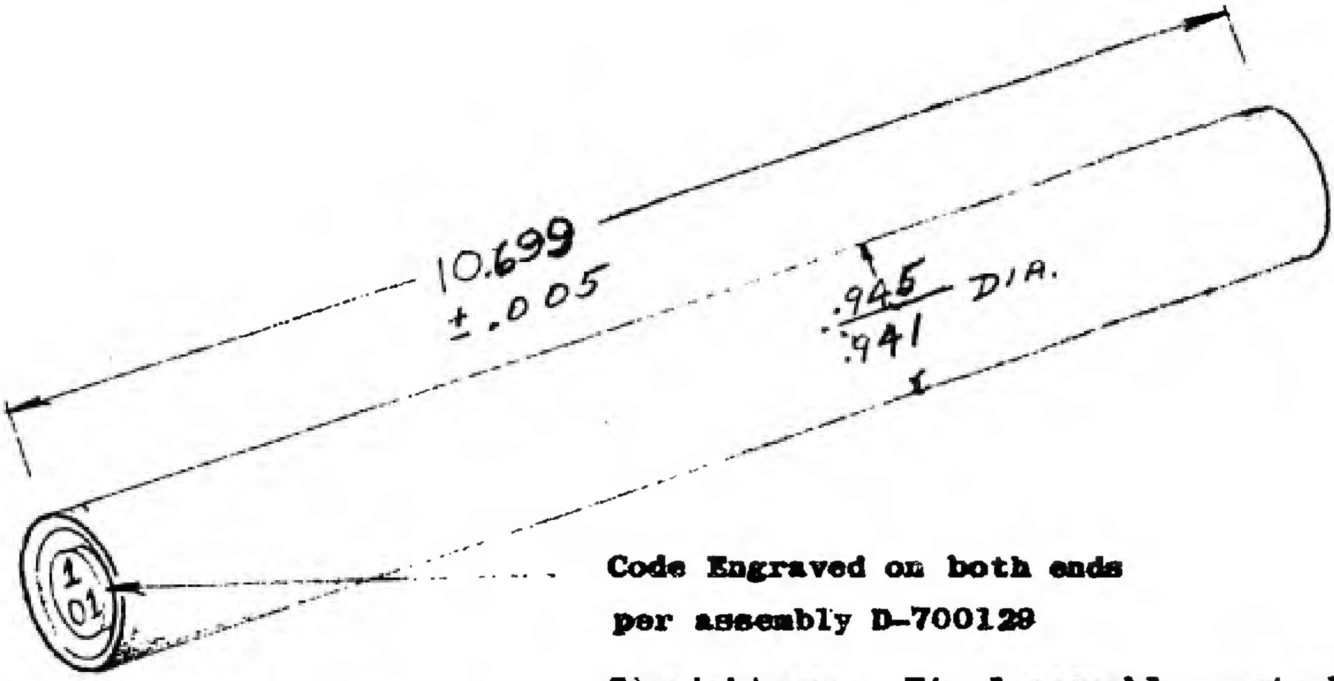
COBALT ENCAPSULATION SIZING DIE

CURTISS-WRIGHT Corp.

PRINCETON, N.J

REFERS TO – SECTION 6.5

Fig 3-4/61 A-700417



Code Engraved on both ends
per assembly D-700129

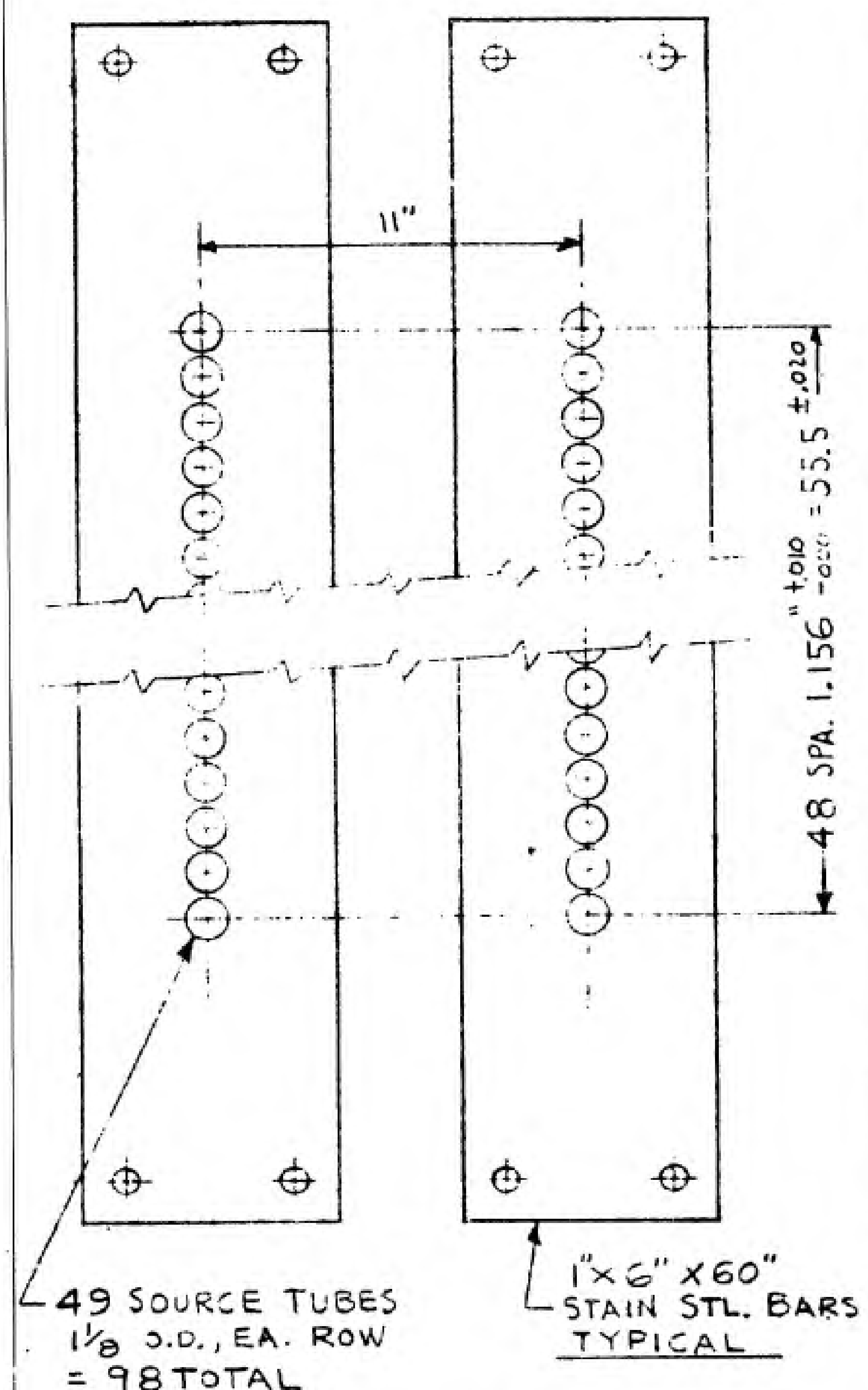
Straightness - Final assembly must slide through 11 inch long tube having a max. inside diameter of .960

CURTISS-WRIGHT CORPORATION
Princeton, N. J.

COBALT ENCAPSULATION
PERSPECTIVE
Drawing A-700405

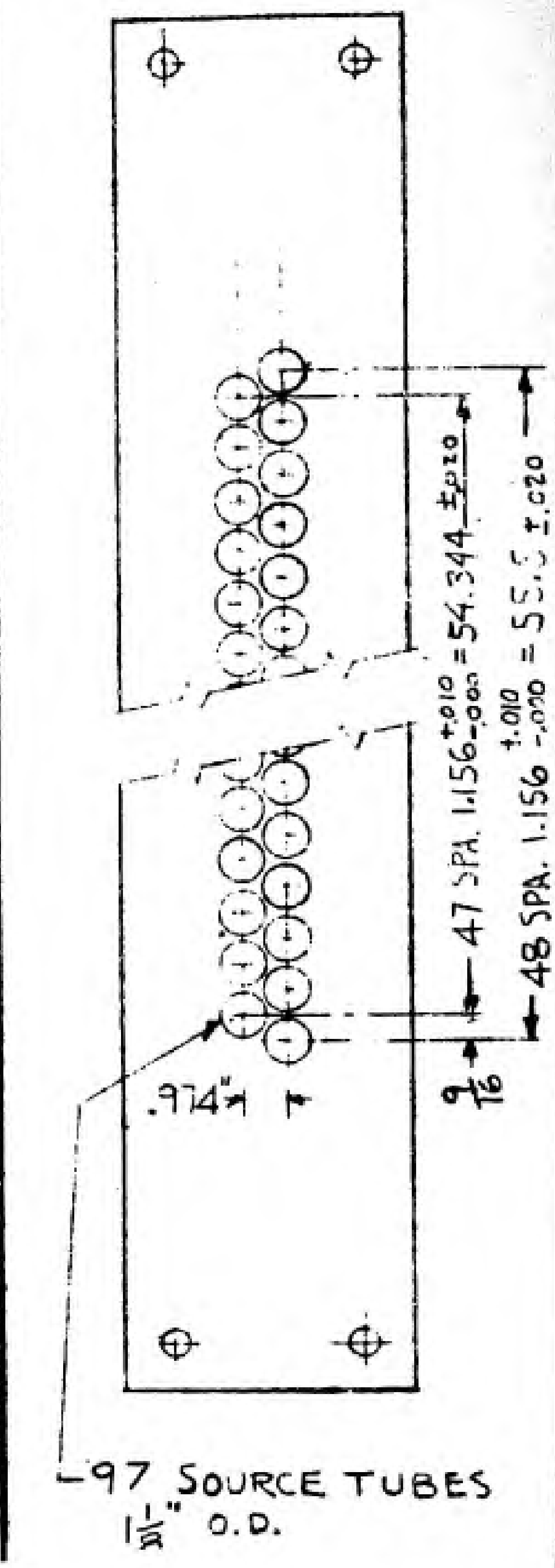
Section 9.8 12/21/60

Fig 3-12



11"
48 SPA. 1.156" +.010 -.000 = 55.5 ±.020
49 SOURCE TUBES 1⅛ O.D., EA. ROW = 98 TOTAL
1"×6"×60" STAIN STL. BARS TYPICAL

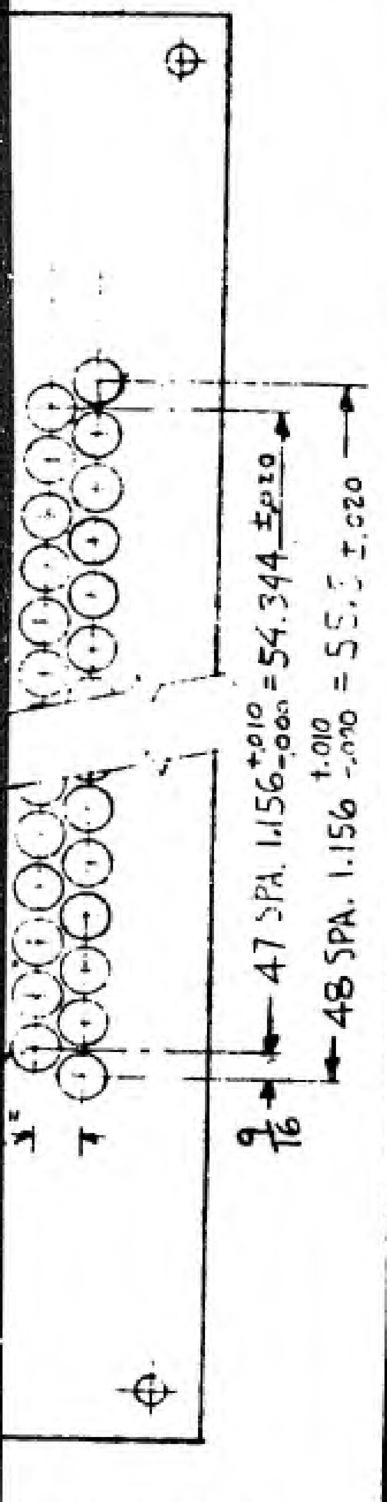
Fig. - G1



47 SPA. 1.156 +.010 -.000 = 54.344 ±.020
48 SPA. 1.156 +.010 -.000 = 55.5 ±.020
.974"
9/16
97 SOURCE TUBES 1½" O.D.

Fig - G2

REV	DESCRIPTION	DATE	APPROVAL
A	TUBE SPA. WAS 1 1/8, 60" & 36" WAS 72"	11-29-60	RGI



...URCE TUBES
...D.

...ig - G2

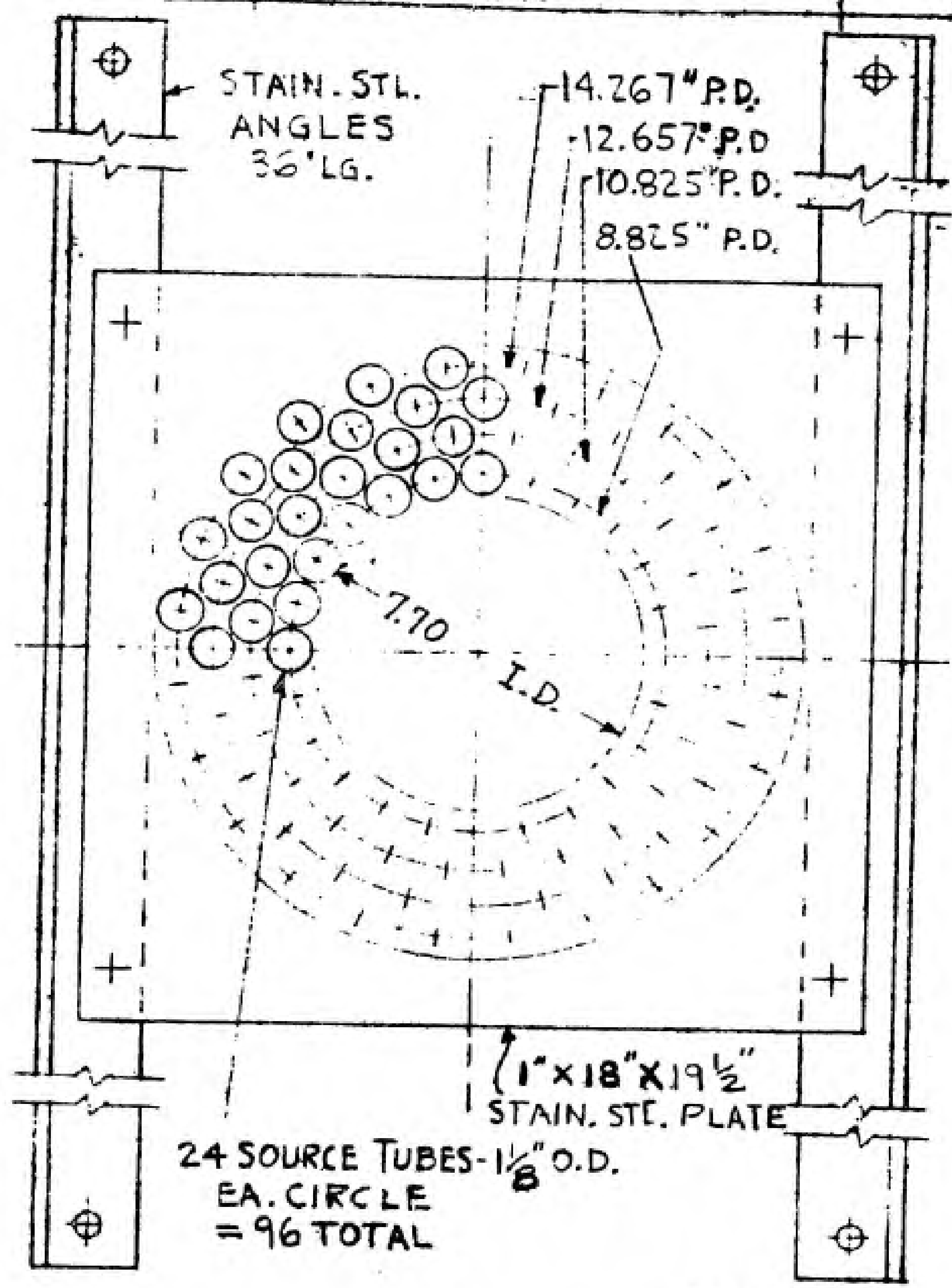


Fig. - G3

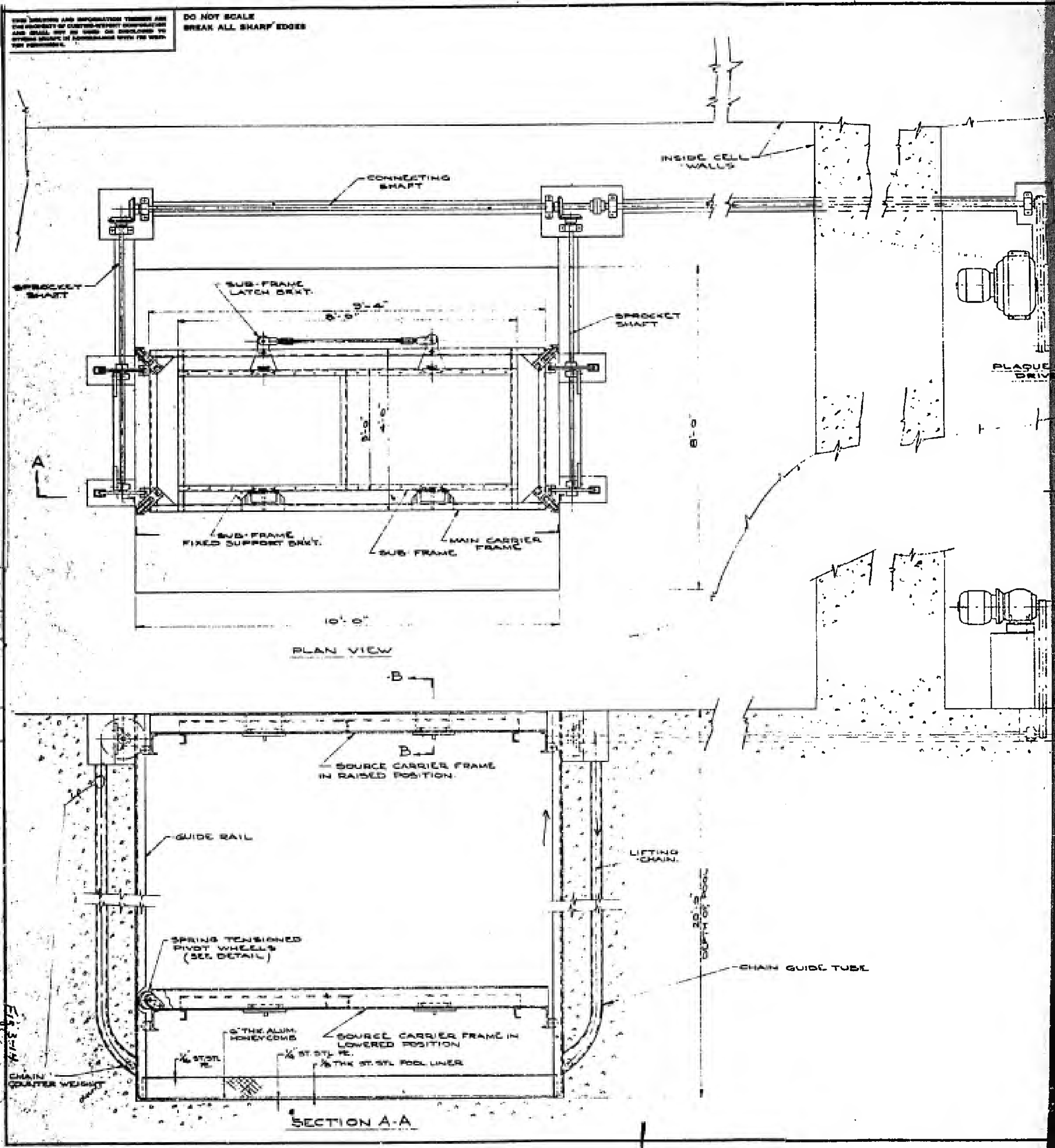
2

Fig 3-13

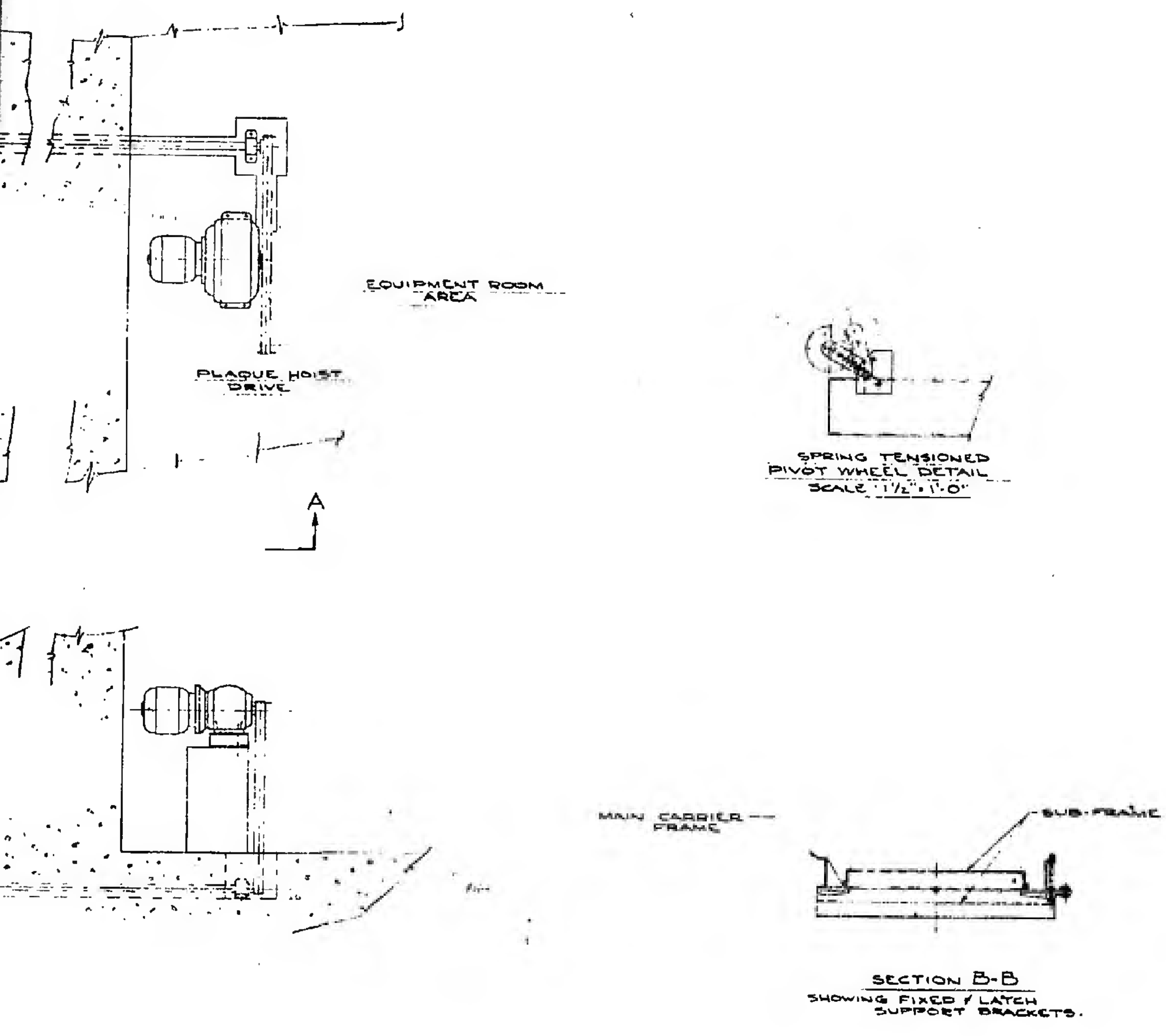
CURTISS-WRIGHT CORP.
PRINCETON DIVISION
PRINCETON, N.J. U.S.A.

- F.P.D.I. -
SOURCE ARRANGEMENTS

B700161A


DO NOT SCALE
BREAK ALL SHARP EDGES
INSIDE CELL WALLS
CONNECTING SHAFT
SPROCKET SHAFT
SUB-FRAME LATCH BRKT.
9'-4"
8'-0"
SPROCKET SHAFT
5'-0"
4'-0"
8'-0"
A
PLAQUE DRIVE
SUB-FRAME FIXED SUPPORT BRKT.
SUB-FRAME
MAIN CARRIER FRAME
10'-0"
PLAN VIEW
B
B
SOURCE CARRIER FRAME IN RAISED POSITION
GUIDE RAIL
LIFTING CHAIN
20'-0" DEPTH OF POOL
SPRING TENSIONED PIVOT WHEELS (SEE DETAIL)
CHAIN GUIDE TUBE
6" THK. ALUM. HONEYCOMB
SOURCE CARRIER FRAME IN LOWERED POSITION
1/4" ST. STL. PL.
1/8" THK. ST. STL. POOL LINER
CHAIN COUNTER WEIGHT
Fig 3-14
SECTION A-A

REVISIONS			
SYM.	DESCRIPTION	DATE	APPROVAL



D-700118

DET.	PART NO.	REQ'D	DESCRIPTION	MAT'L & SIZE	MAT'L SPEC.

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACT. ± 1/64 CASTING ± 1/16
DECIMAL ± .005 FORGING ± 1/16
ANGULAR ± 1°
SPECIFICATION:
HEAT TREAT:
FINISH:

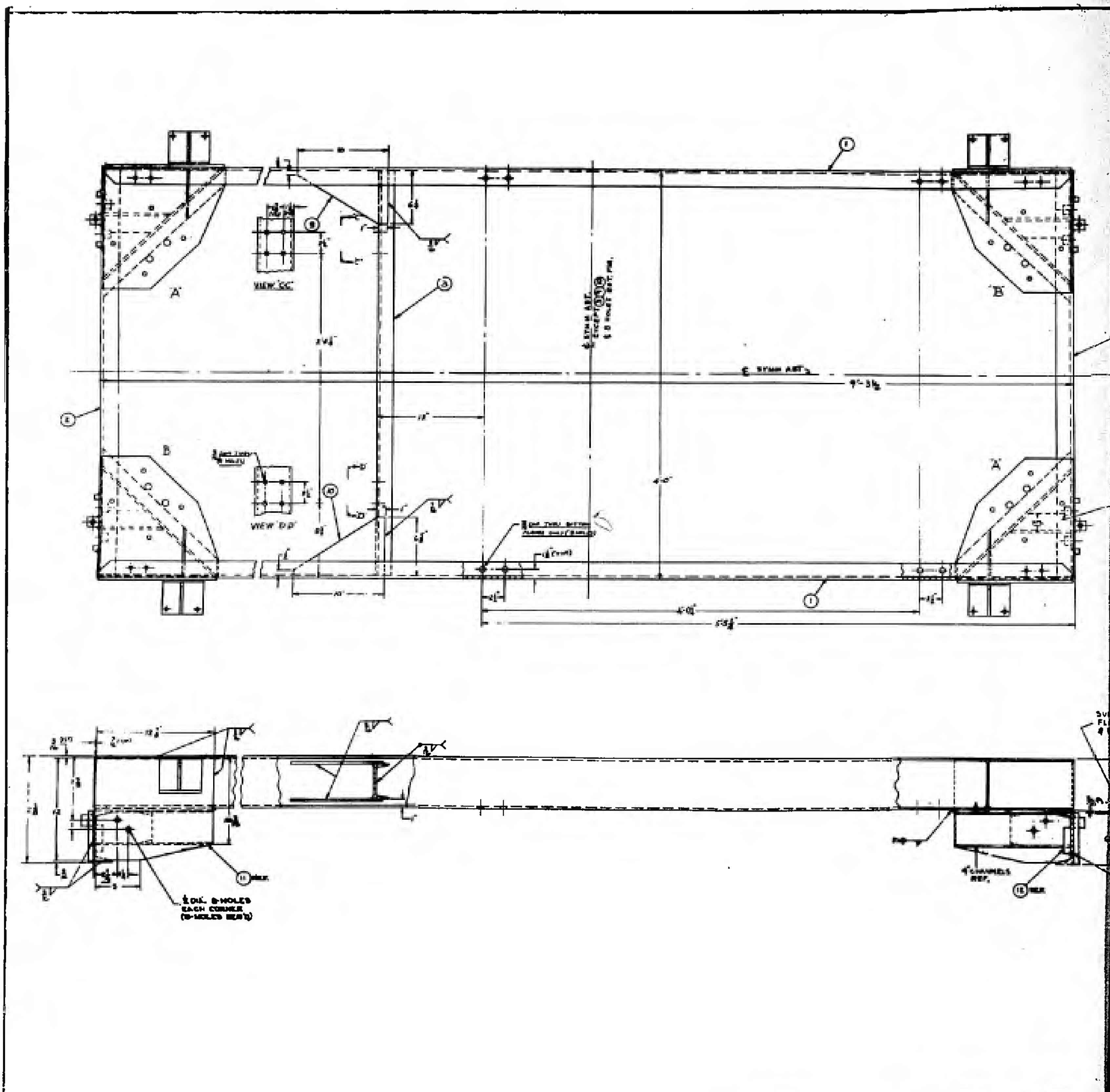
	NAME	DATE
DRAWN	J.A.K.	4/13/60
CHECKED		
APP'D		
ENG. APP'L		

TITLE:
F. P. D. I.
SOURCE CARRIER FRAME
& HOISTING ARRANGEMENT
CONCEPTUAL LAYOUT

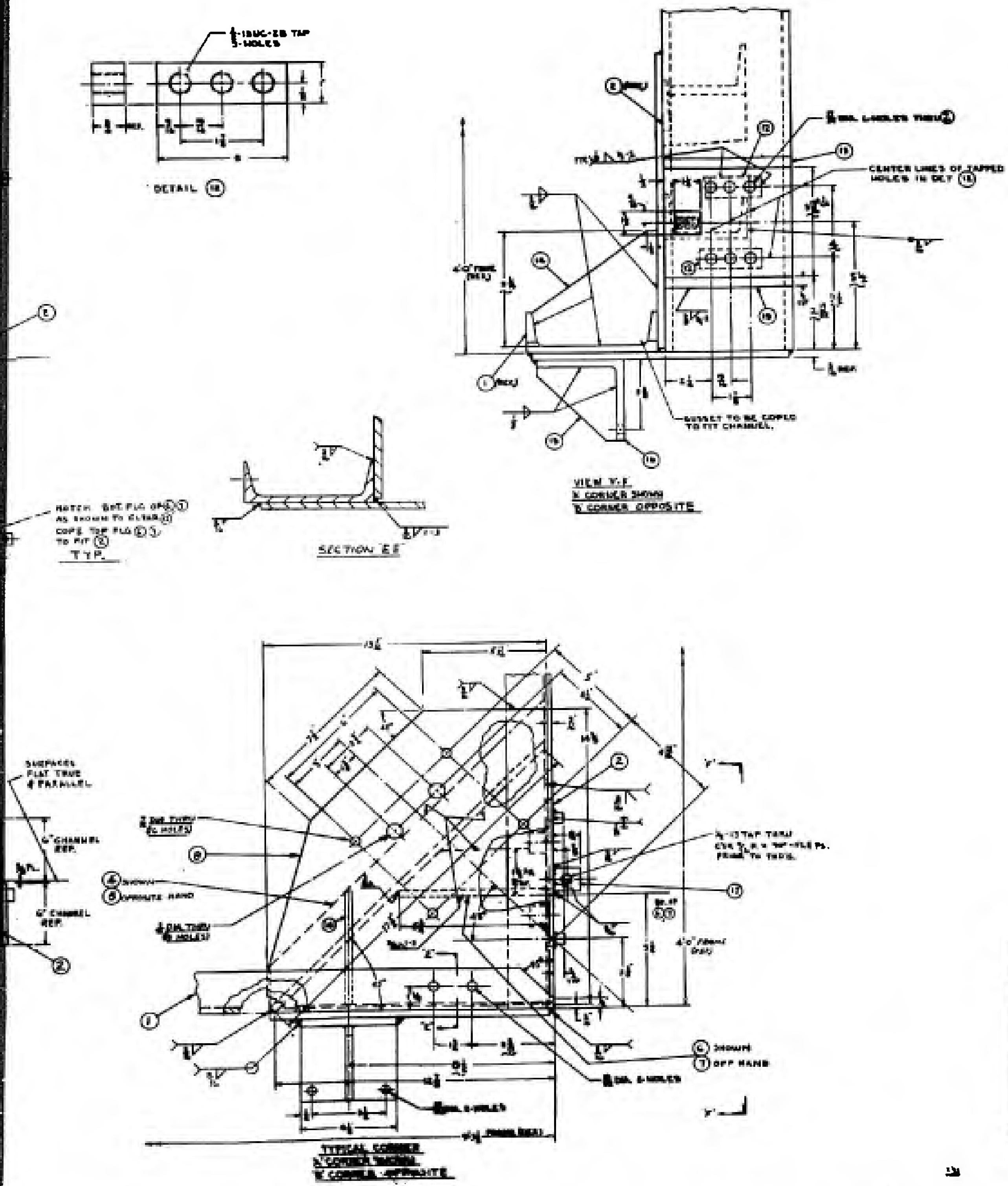
SCALE 3/4" = 1'-0" Fig 3-14

CURTISS-WRIGHT CORP.
PRINCETON DIVISION
PRINCETON, NEW JERSEY

D-700118



VIEW 'C-C'
VIEW 'D-D'
'A'
'B'



NOTES:
1. FINISHED FRAME TO BE ANODIZED FOR CORROSION RES.

17		4	BAR	[illegible]
16		4	ANGLE	[illegible]
15		4	GUSSET	[illegible]
14		4	GUSSET	[illegible]
13		4	BAR	[illegible]
12		8	BAR	[illegible]
11		4	PLATE	[illegible]
10		2	GUSSET	[illegible]
9		2	GUSSET	[illegible]
8		4	GUSSET	[illegible]
7		2	CHANNEL	[illegible]
6		2		[illegible]
5		2		[illegible]
4		2		[illegible]
3		2		[illegible]
2		2		[illegible]
1		2	CHANNEL	[illegible]

MAIN FRAME
SOURCE PLATFORM
USED ON

FIG 3-15

2

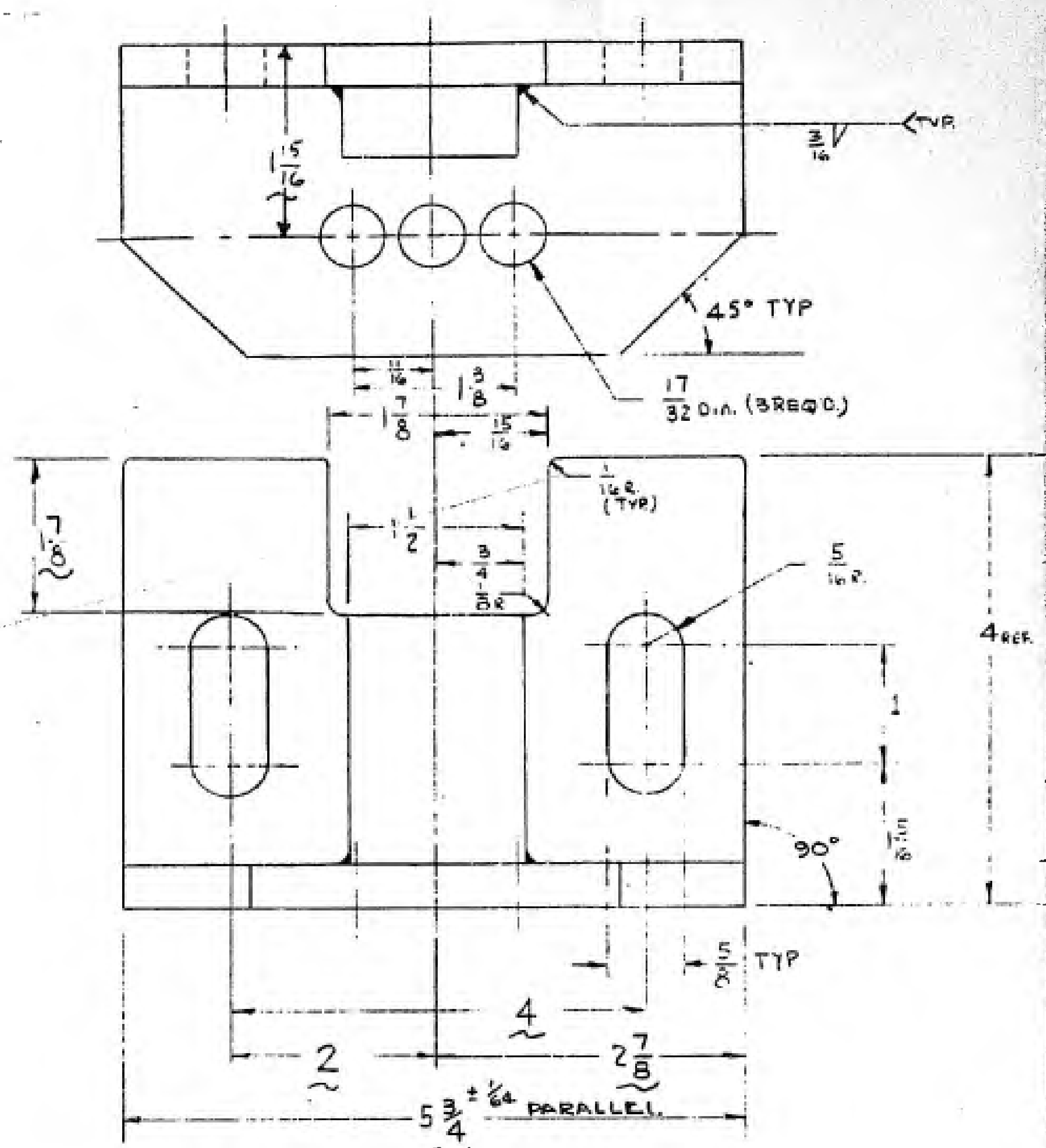
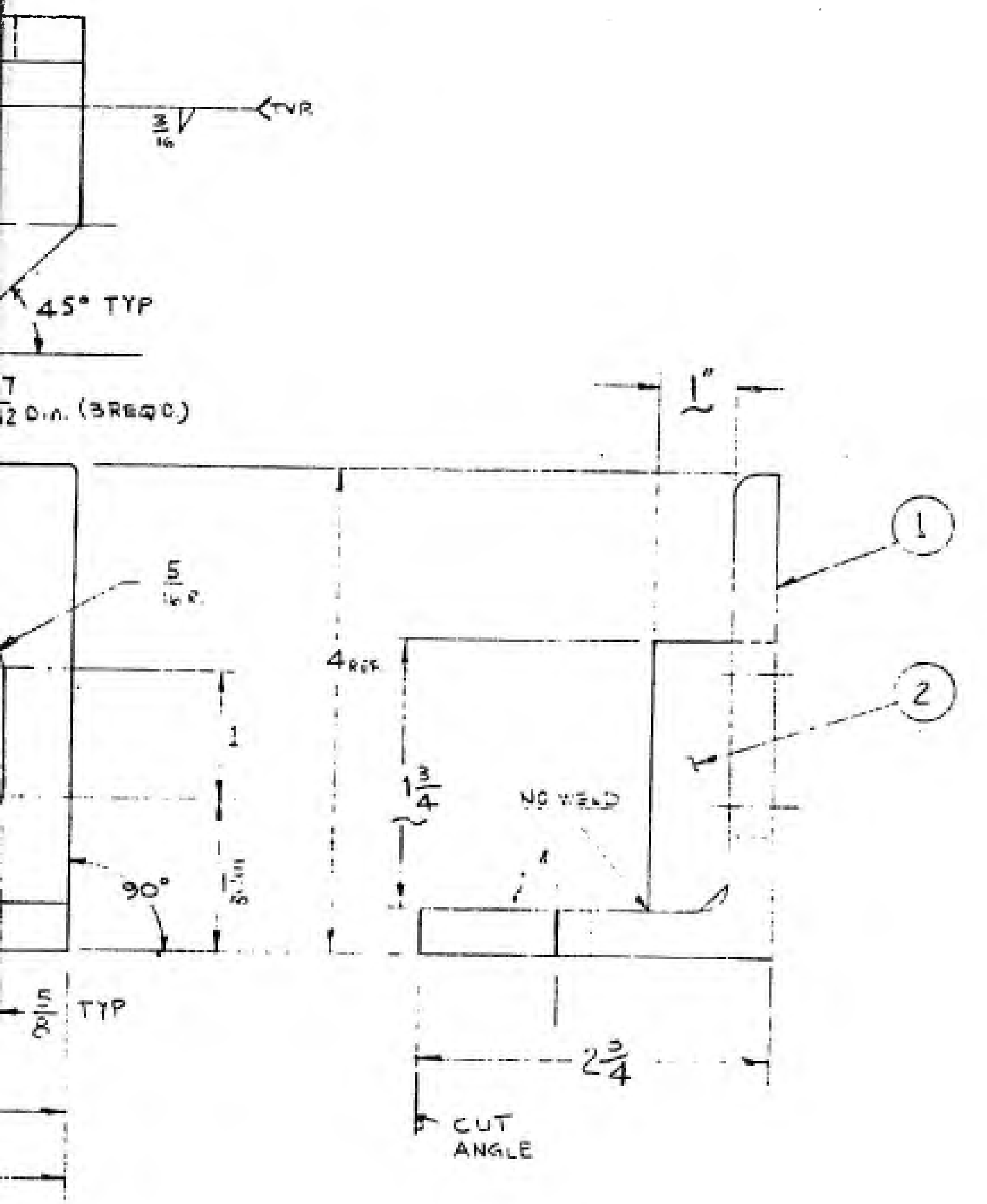


Fig 3-16

UNLESS OTHER
DIMENSIONS
TOLERANCES
FRACT. ± 1/64
DECIMAL ± .005
ANGULAR ± 1°
SPECIFICATION:
HEAT TREAT:
FINISH: ANOD



C-100274

DET.	PART NO.	REQ'D	DESCRIPTION	MAT'L & SIZE	MAT'L SPEC.
2		2	BAR	1" × 1 1/2 × 1 3/4	ALUM. 606T-T6
1		1	ANGLE	3/8 × 3 × 4 × 5 3/4 LG.	ALUM 606T-T6

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACT. ± 1/64 CASTING ± 1/16
DECIMAL ± .005 FORGING ± 1/16
ANGULAR ± 1°

SPECIFICATION:

HEAT TREAT:

FINISH: ANODIZE.

	NAME	DATE
DRAWN	D.K.	11-1-60
CHECKED	R.G.	12/15/60
APP'D		
ENG. APP'L		

TITLE: BRACKET-CABLE

4 REQ'D PER UNIT 2

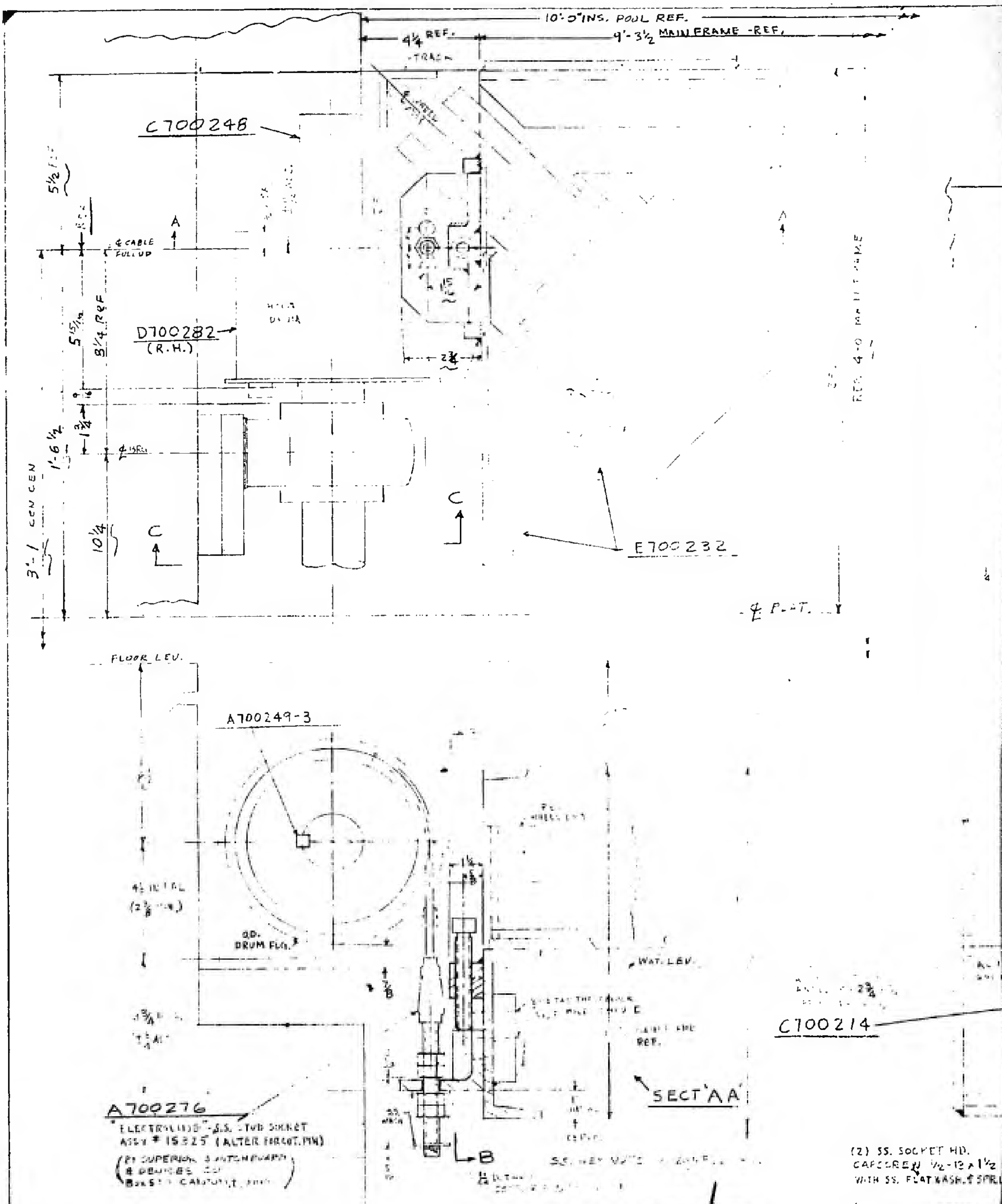
SCALE FULL

Fig 3-16

CURTISS-WRIGHT CORP.
PRINCETON DIVISION
PRINCETON, NEW JERSEY

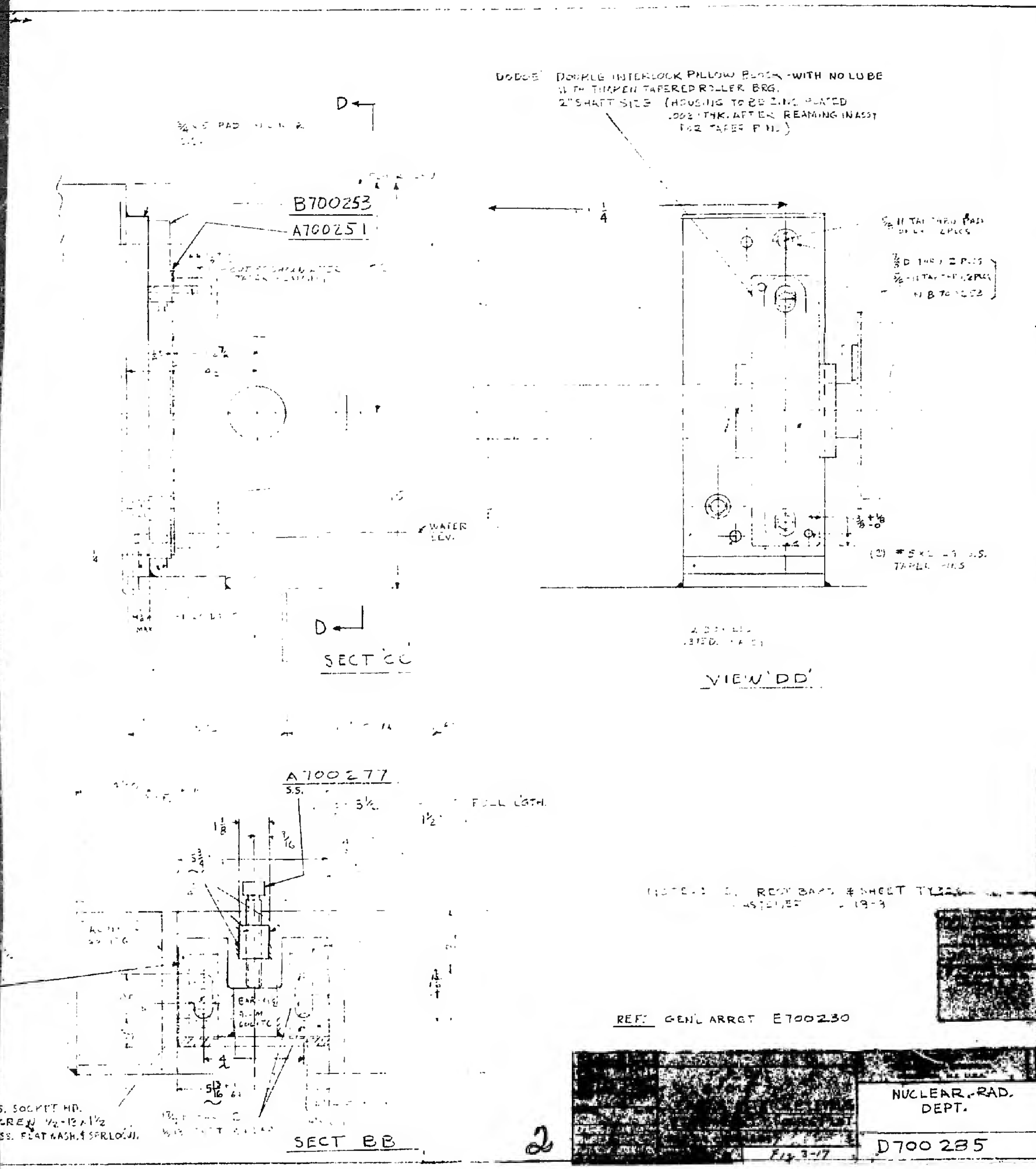
C-100274

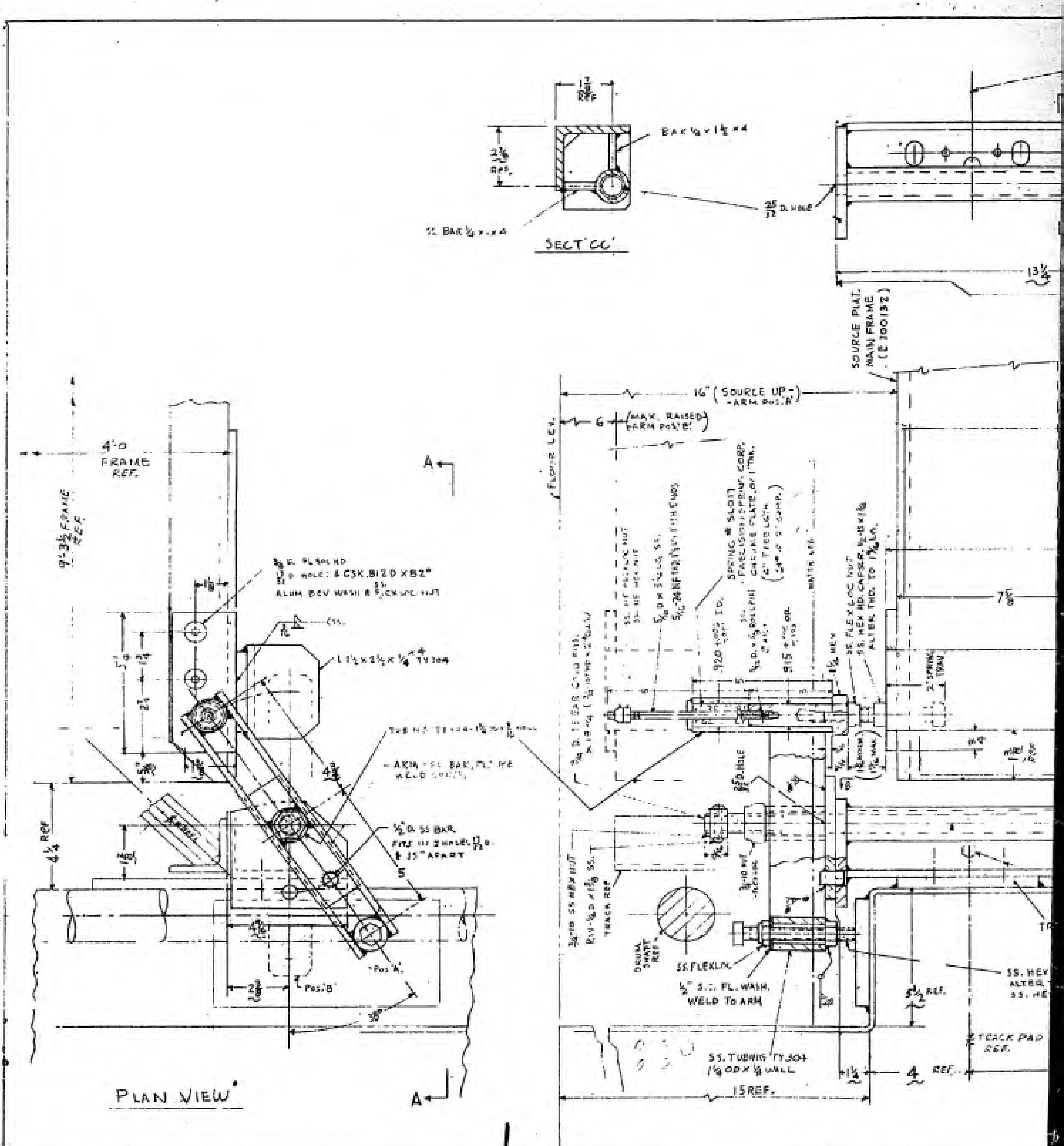
USED ON C700285



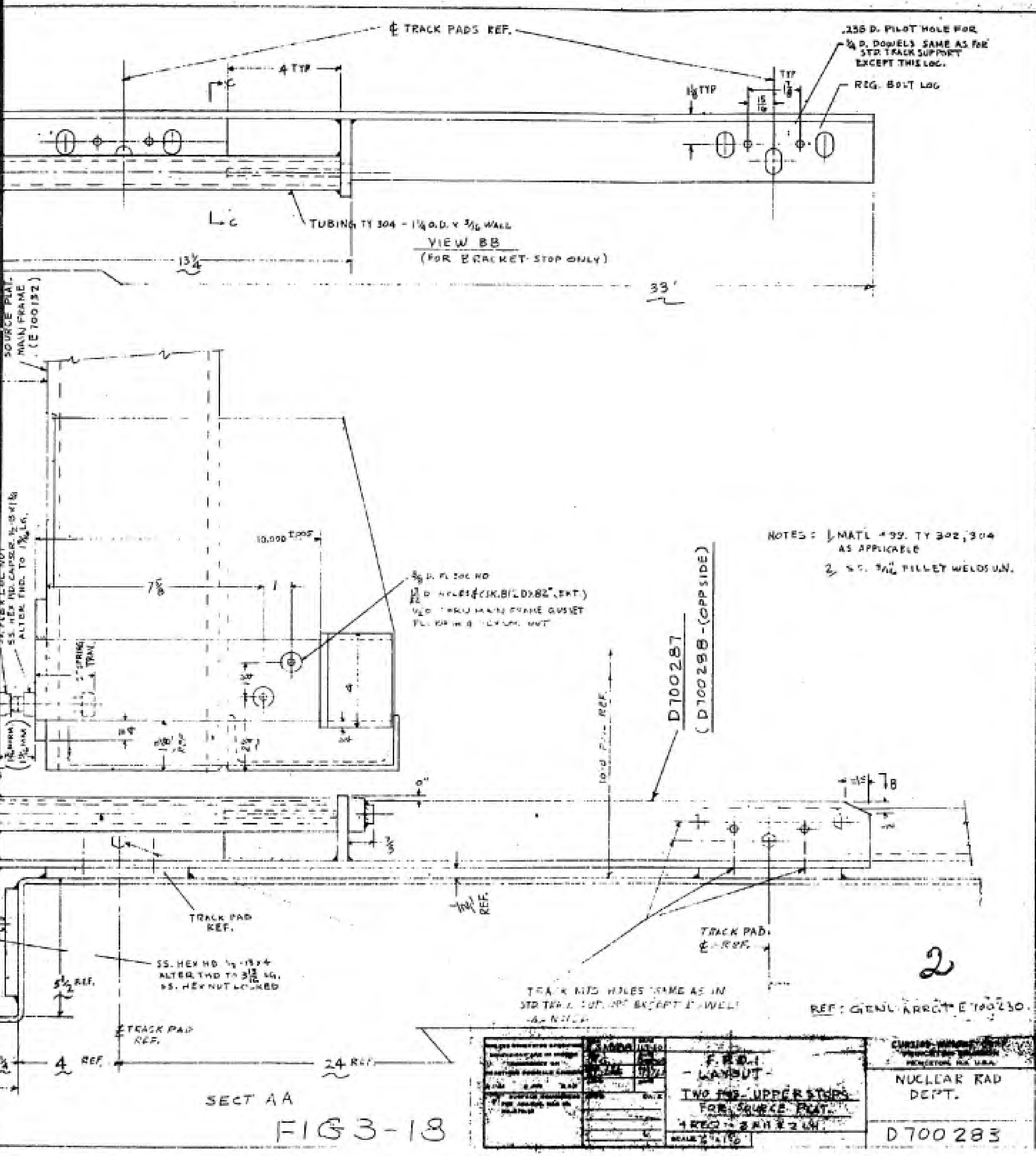
10'-0" INS. POOL REF.
4¼ REF.
9'-3½ MAIN FRAME -REF.
C700248
5½ REF.
A
℄ CABLE PULLUP
D700282
(R.H.)
5 15/16
8¼ REF
2¾
1¾
1'-6½
3'-1 CEN CEN
10¼
C
C
E700232
℄ PLAT.
FLOOR LEV.
A700249-3
O.D. DRUM FLG.
WAT. LEV.
C700214
SECT 'AA'
A700276
"ELECTROLINE" - S.S. STUD SIGNET ASSY # 15325 (ALTER FOR OUT. PIN)
B
(2) SS. SOCKET HD. CAPSCREW ½-13 x 1½ WITH SS. FLAT WASH. & SPRL.

Fig 3-19


DODGE DOUBLE INTERLOCK PILLOW BLOCK - WITH NO LUBE
WITH TIMKEN TAPERED ROLLER BRG.
2" SHAFT SIZE
B700253
A700251
WATER LEV.
SECT 'CC'
VIEW 'DD'
A700277
S.S.
FULL LGTH.
SECT BB
REF: GEN'L ARRGT E700230
NUCLEAR RAD. DEPT.
D700 285
Fig 3-17
2

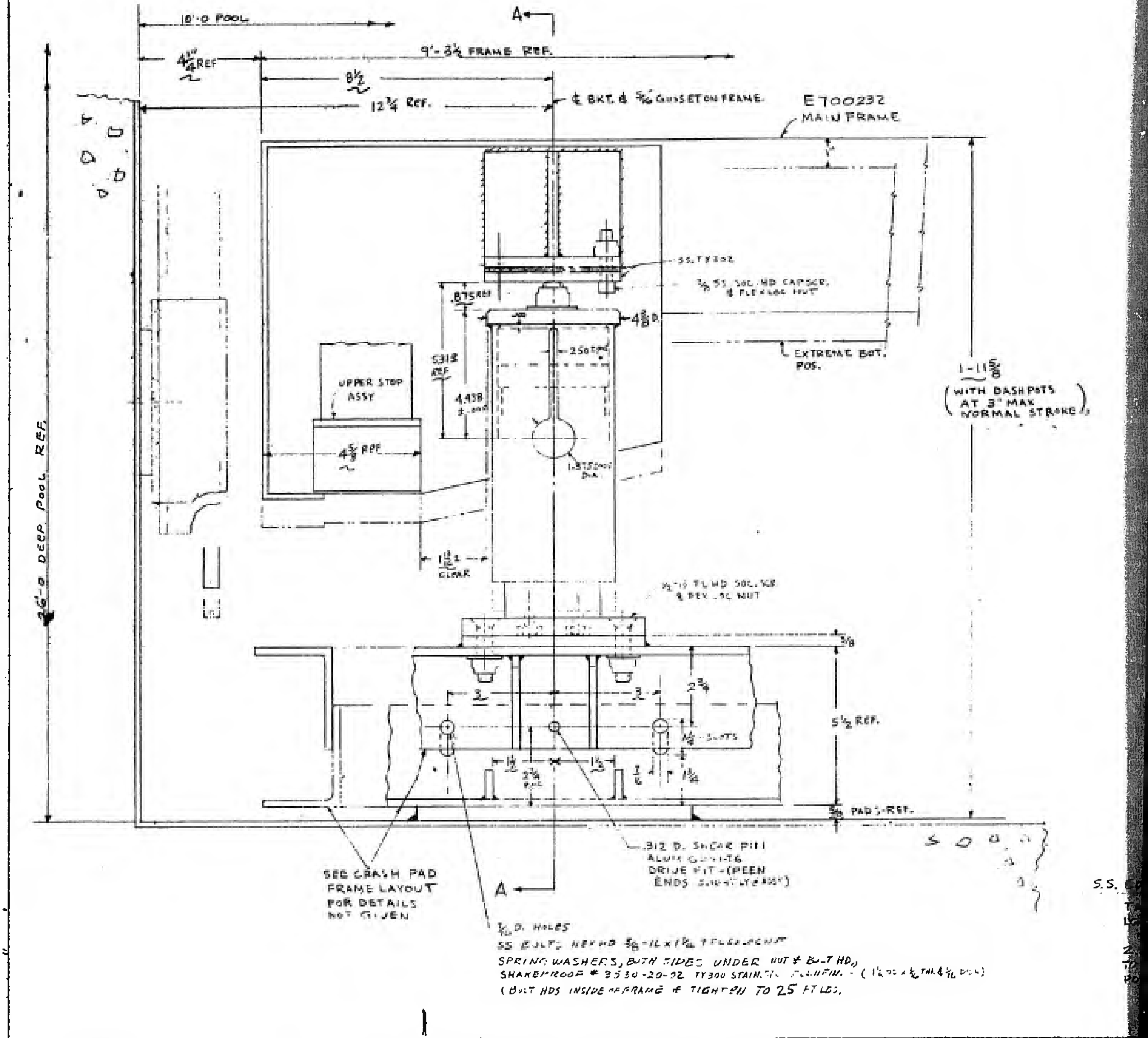


SECT 'CC'
PLAN VIEW
4'-0 FRAME REF.
SOURCE PLAT. MAIN FRAME (E 300132)
16" (SOURCE UP - ARM POS. 'A')
6 (MAX. RAISED ARM POS. 'B')
FLOOR LEV.
SS. TUBING TY.304 1¼ OD x ⅛ WALL
15 REF.
½" SS. FL. WASH. WELD TO ARM
SS. FLEXLOC
DRUM SHAFT REF.
TRACK PAD REF.
4 REF.
POS. 'A'
POS. 'B'

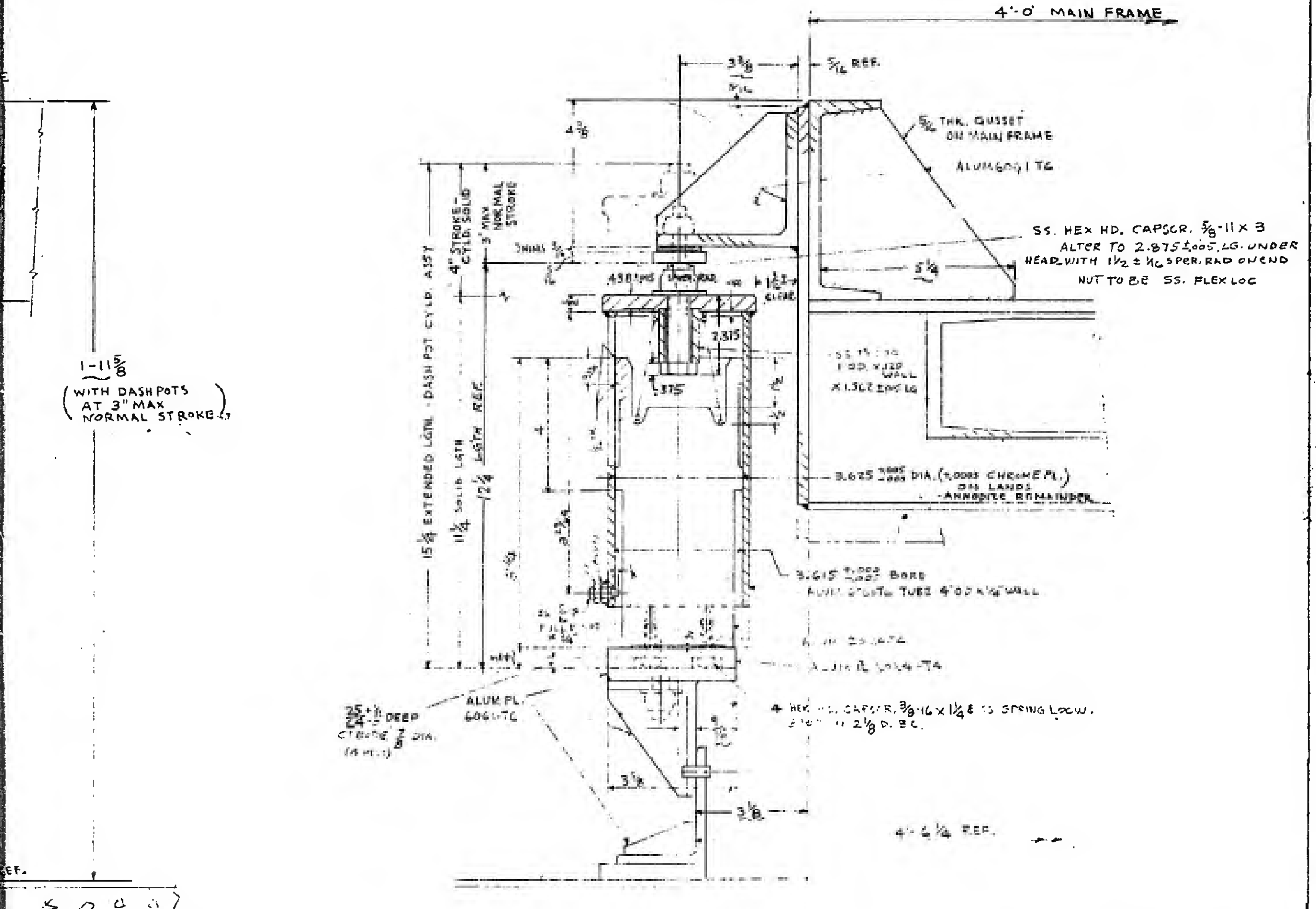


℄ TRACK PADS REF.
.250 D. PILOT HOLE FOR 1/4 D. DOWELS SAME AS FOR STD. TRACK SUPPORT EXCEPT THIS LOC.
REG. BOLT LOC
TUBING TY 304 - 1 1/4 O.D. x 3/16 WALL
VIEW BB
(FOR BRACKET STOP ONLY)
NOTES: 1. MATL ... TY 302, 304 AS APPLICABLE
TRACK PAD REF.
TRACK PAD ℄ REF.
℄ TRACK PAD REF.
D700287
(D700288 - (OPP SIDE))
SECT AA
2
REF: GENL ARRGT E 700230.
NUCLEAR RAD DEPT.
LAYOUT
D700283

FIG 3-18



10'-0 POOL
9'-3½ FRAME REF.
4¼" REF
8½
12¾ REF.
℄ BKT. & 5/16 GUSSET ON FRAME.
E700232
MAIN FRAME
26'-0 DEEP POOL REF.
UPPER STOP ASSY
4⅝ REF.
.875 REF
5.313 REF
4.438
EXTREME BOT. POS.
1-11⅝
(WITH DASHPOTS AT 3" MAX NORMAL STROKE)
1 13/32 CLEAR
5½ REF.
⅝ PADS-REF.
SEE CRASH PAD FRAME LAYOUT FOR DETAILS NOT GIVEN
A
A

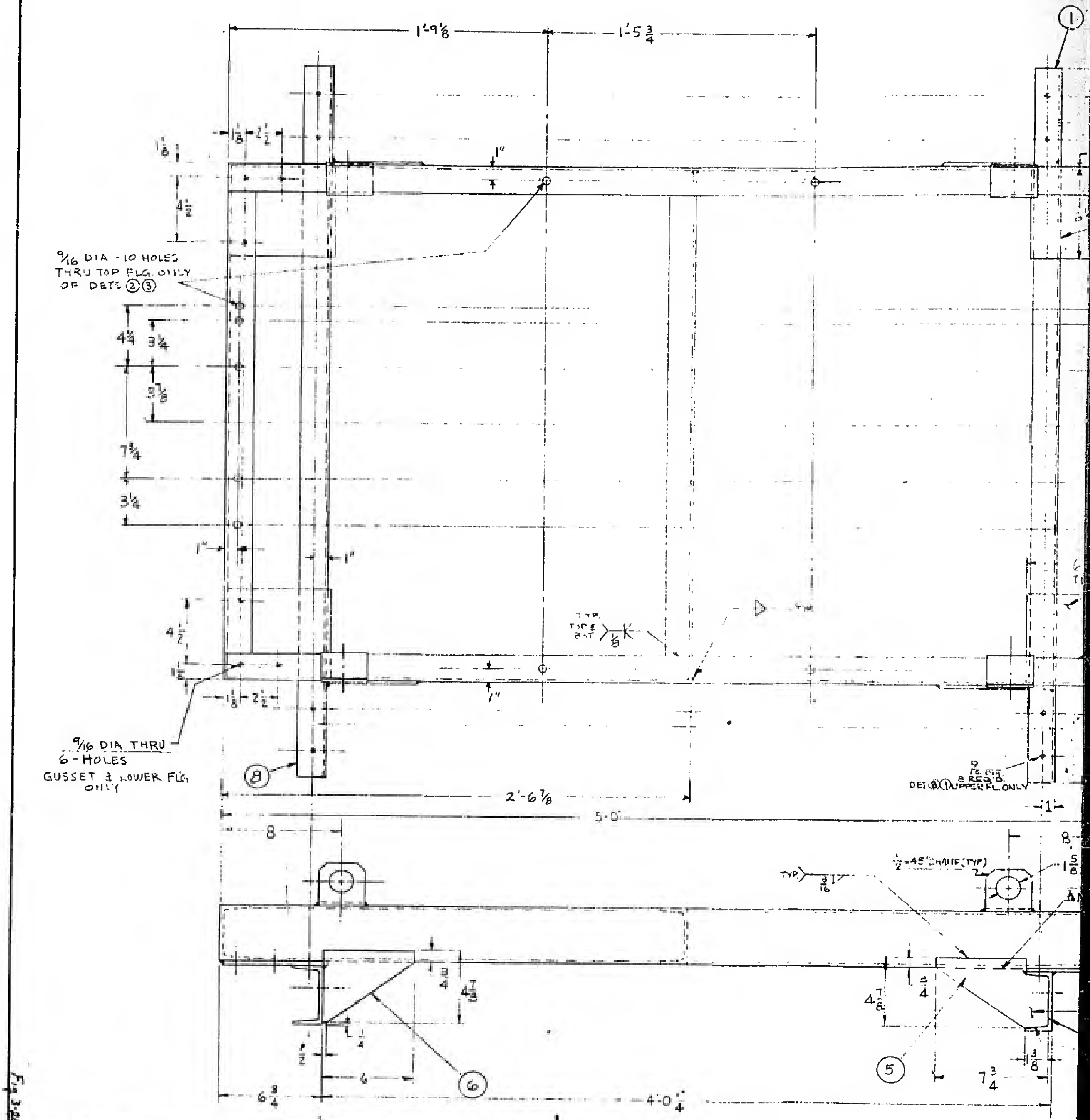


S.S. CONICAL SPRING REQ'T.:
TAPERING-ID. 2 1/2 TO 1 1/4
LGTH WITH CYLD EXTENDED = 6 1/2
" " " CLOSED = 2 1/2
2 CLOSED COILS EA END.
TO POSITIVE RAISE FLD TO EXTEND POS. (CYLD. WT. ... = 2.25#)

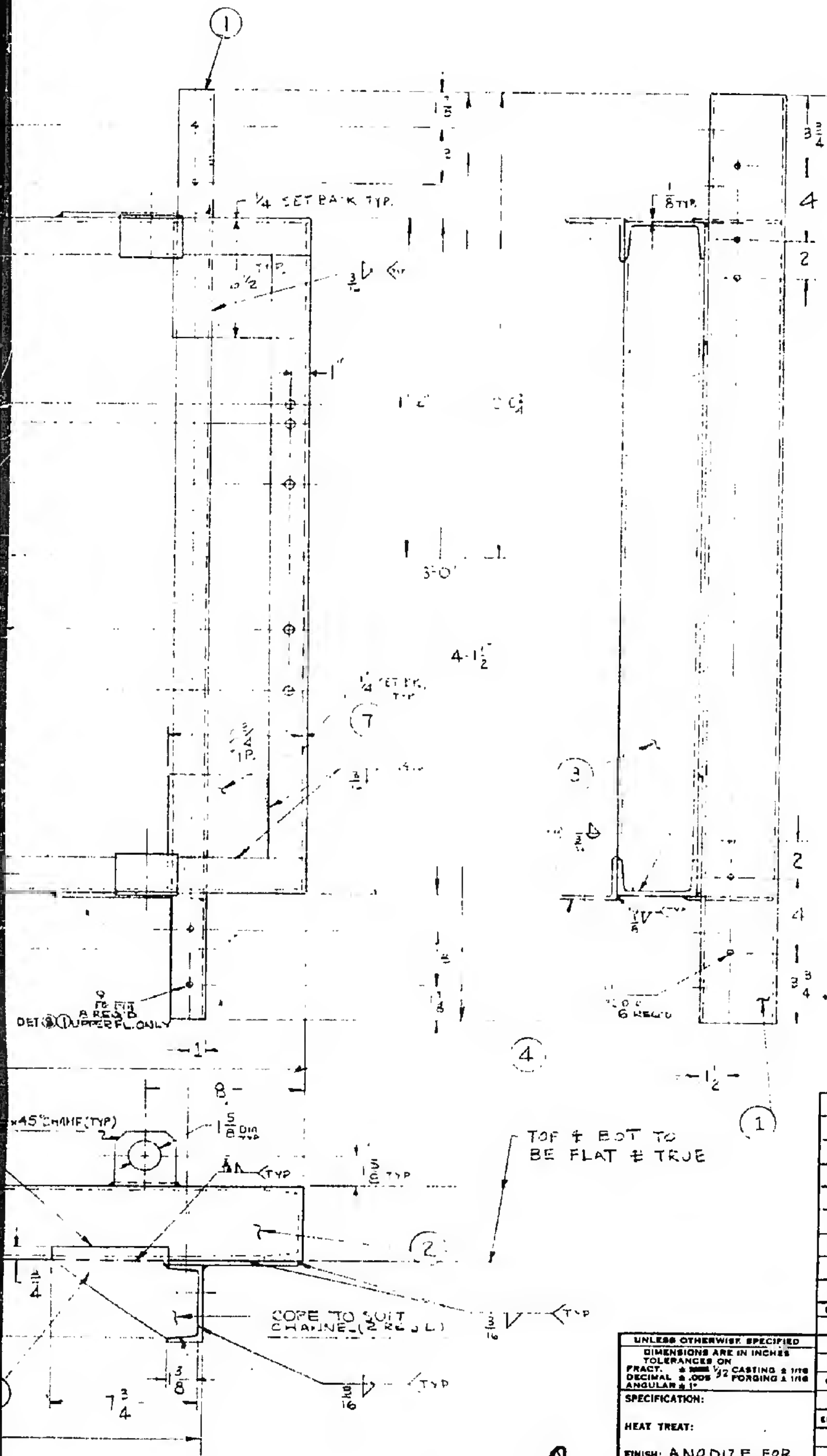
F.P.D.I - LAYOUT - DASHPOT LOWER STOPS FOR SOURCE PLAT 4 REQ	CURTISS-WRIGHT CORP. PRINCETON DIVISION PRINCETON, N.J. U.S.A.	NUCLEAR RAD. DEPT.
SCALE 6" = 1'-0"		D700284

FIG 3-19

DO NOT SCALE
BREAK ALL SHARP EDGES



REVISIONS			
SYM.	DESCRIPTION	DATE	APPROVAL



D-700233

DET.	PART NO.	REQ'D	DESCRIPTION	MAT'L & SIZE	MAT'L SPEC.
8		1	CHANNEL	4⊏ 2.5# x 4'-1 1/2	ALUM 6061-T6
7		4	PLATE	3/8 x 6 1/2 x 6 3/4	ALUM-6061-T6
6		2	GUSSET	1/4 x 4 7/8 x 6	ALUM-6061-T6
5		2	GUSSET	1/4 x 4 7/8 x 7 3/4	ALUM-6061-T6
4		4	ANGLE	1/4 x 2 x 3 x 3	ALUM-6061-T6
3		2	CHANNEL	4⊏ 2.5# x 2'-11 3/8"	ALUM-6061-T6
2		2	CHANNEL	4⊏ 2.5# x 5'-0"	ALUM-6061-T6
1		1	CHANNEL	4⊏ 2.5# x 4'-1 1/2	ALUM-6061-T6

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACT. ± 1/32 CASTING ± 1/16
DECIMAL ± .005 FORGING ± 1/16
ANGULAR ± 1°

SPECIFICATION:

HEAT TREAT:

FINISH: ANODIZE FOR CORROSION RES.

	NAME	DATE
DRAWN	D.R.	11-?-60
CHECKED	R.G.	12-27-60
APP'D	[illegible]	[illegible]
ENG. APP'L		

TITLE: F.P.D.I.
SUB FRAME – SOURCE PLATFORM

ONE REQ. PER UNIT

SCALE 3" = 1'-0"

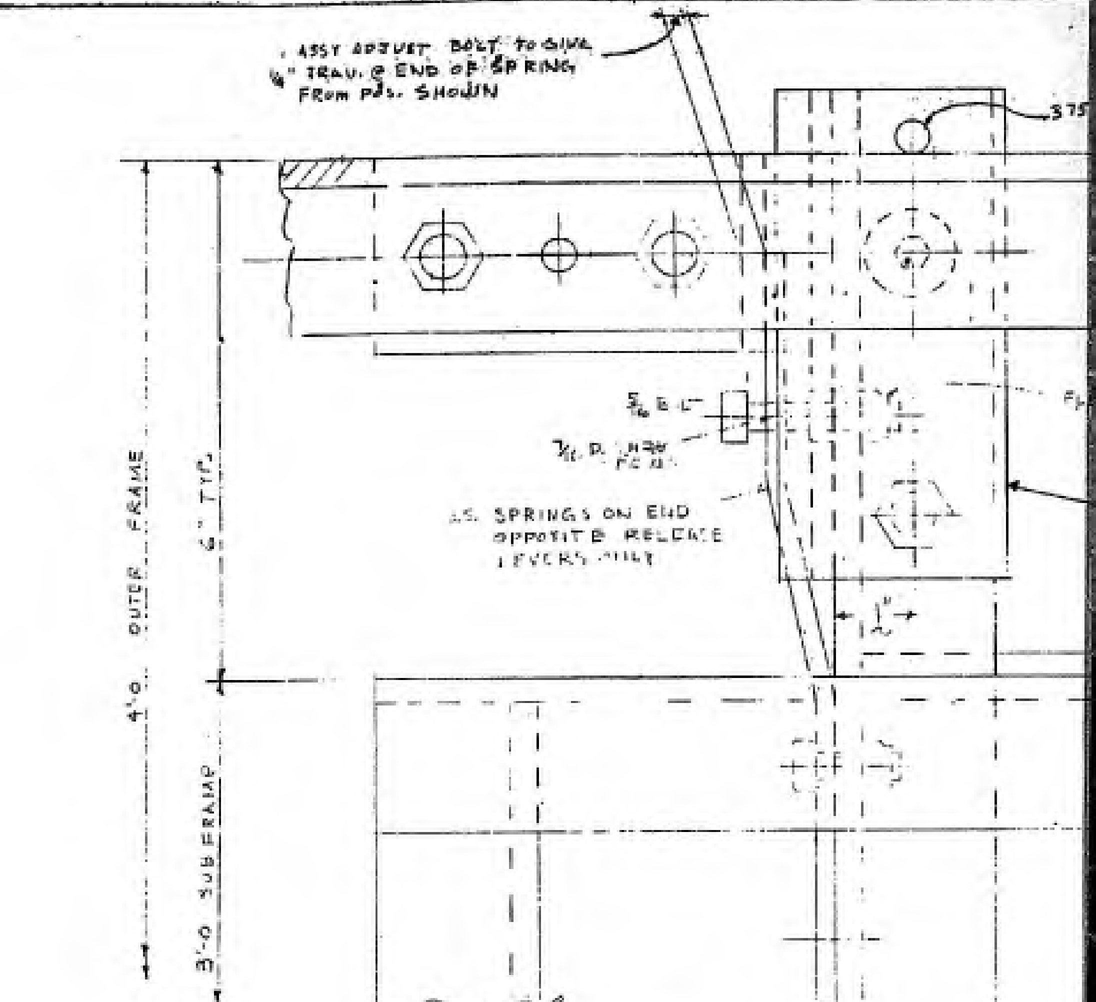
Fig 3-20

CURTISS-WRIGHT CORP.
PRINCETON DIVISION
PRINCETON, NEW JERSEY

D-700233

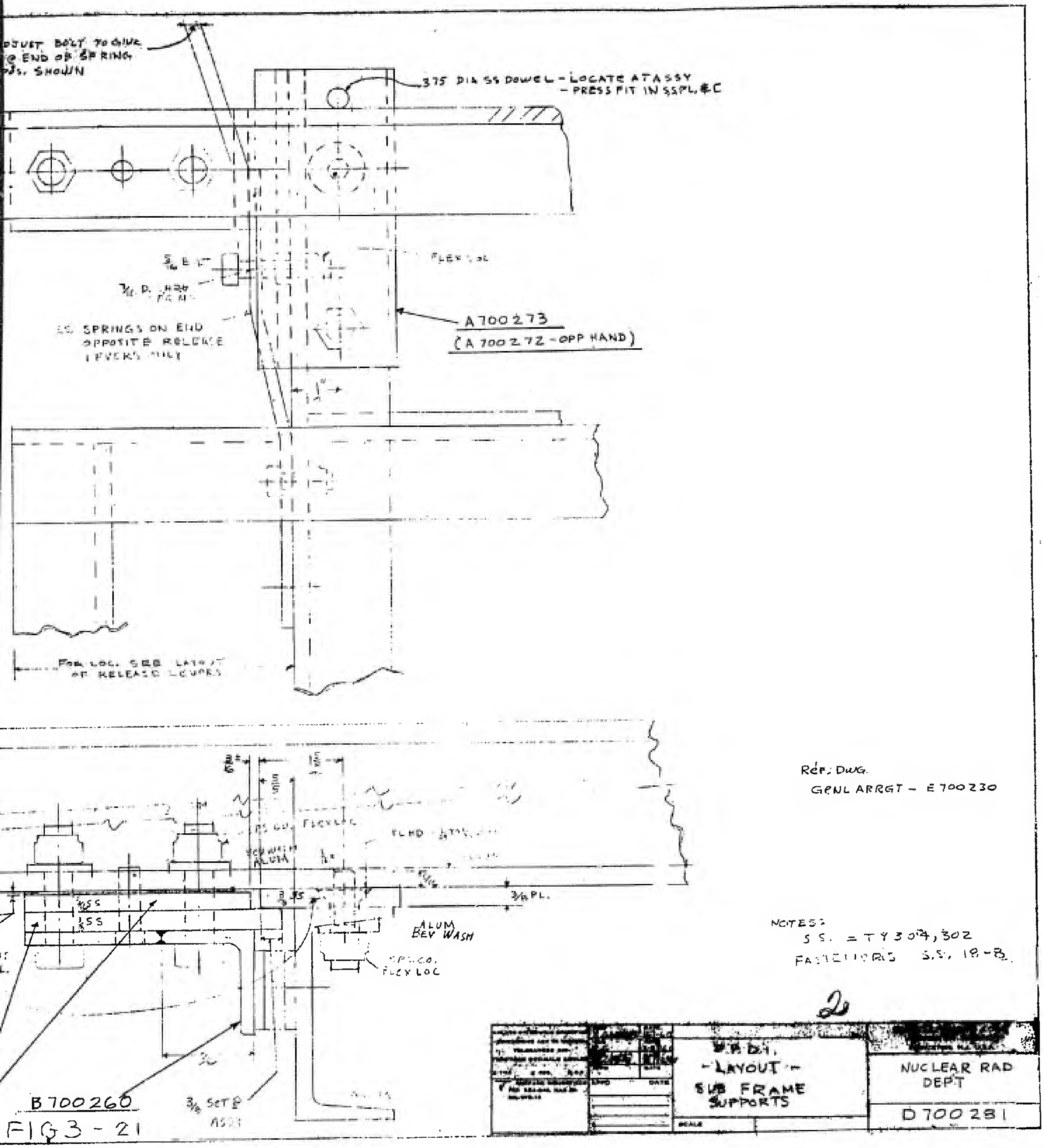
USED ON E700230

2



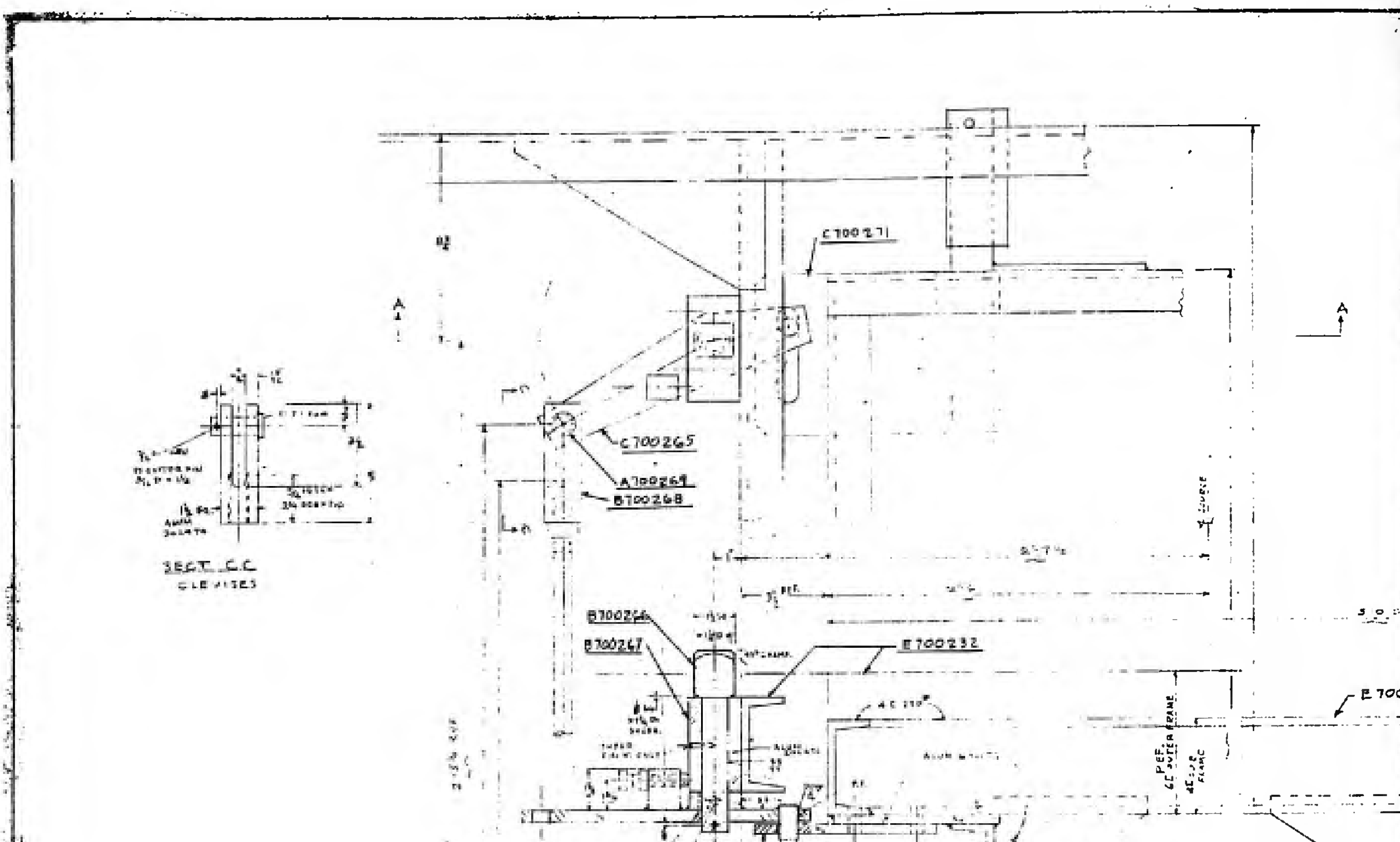
ASSY ADJUST BOLT TO GIVE ¼" TRAV. @ END OF SPRING FROM POS. SHOWN
OUTER FRAME
4'-0
6" TYP.
3'-0 SUBFRAME
SPRINGS ON END OPPOSITE RELEASE LEVERS ONLY
FOR LOC. SEE LAYOUT OF RELEASE LEVERS
OUTER FRAME 6" L 3.62# ALUM
A700252
A700258
A700259
B700260
SLIDING FIT OF THIS PL.

FIG 3-21

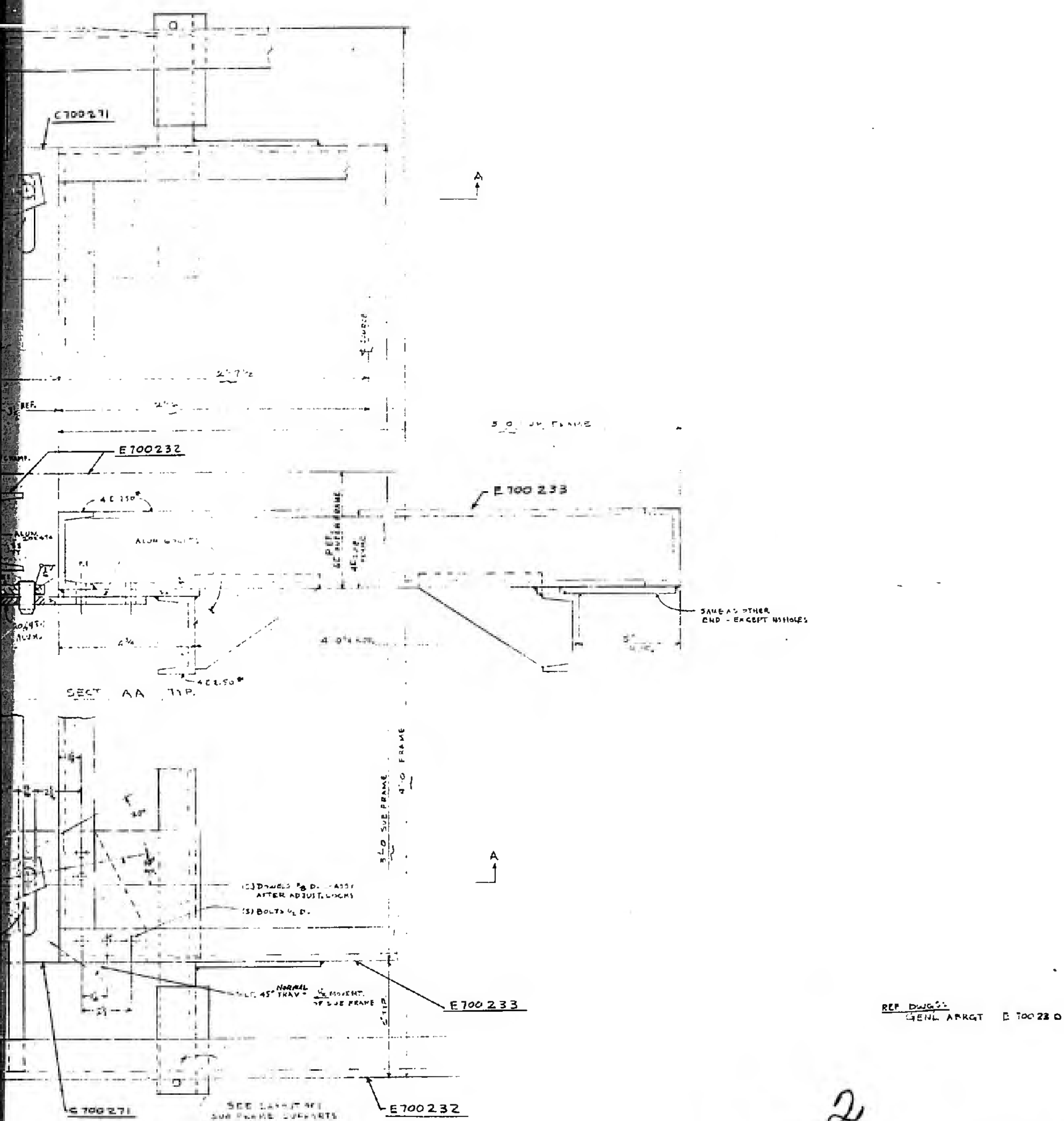


.375 DIA SS DOWEL - LOCATE AT ASSY
- PRESS FIT IN SS PL #C
A 700273
(A 700272 - OPP HAND)
SS SPRINGS ON END OPPOSITE RELEASE LEVERS ONLY
FOR LOC. SEE LAYOUT OF RELEASE LEVERS
ALUM BEV WASH
3/8 PL.
B 700260
3/8 SET
REF: DWG.
GENL ARRGT - E 700230
NOTES:
S.S. = TY 304, 302
FASTENERS S.S. 18-8
2
-LAYOUT-
SUB FRAME SUPPORTS
NUCLEAR RAD DEPT
D 700281

FIG 3 - 21



C700271
C700265
A700269
B700268
SECT. C.C
CLEVISES
B700266
B700267
E700232
SECT. AA TYP.
A700270
B700268
A700269
C700265
E700233
C700271
E700232
SECT. B.B
SHOWING SAFETY SHEAR PIN
FOR ARM - NEAR SIDE ONLY



2

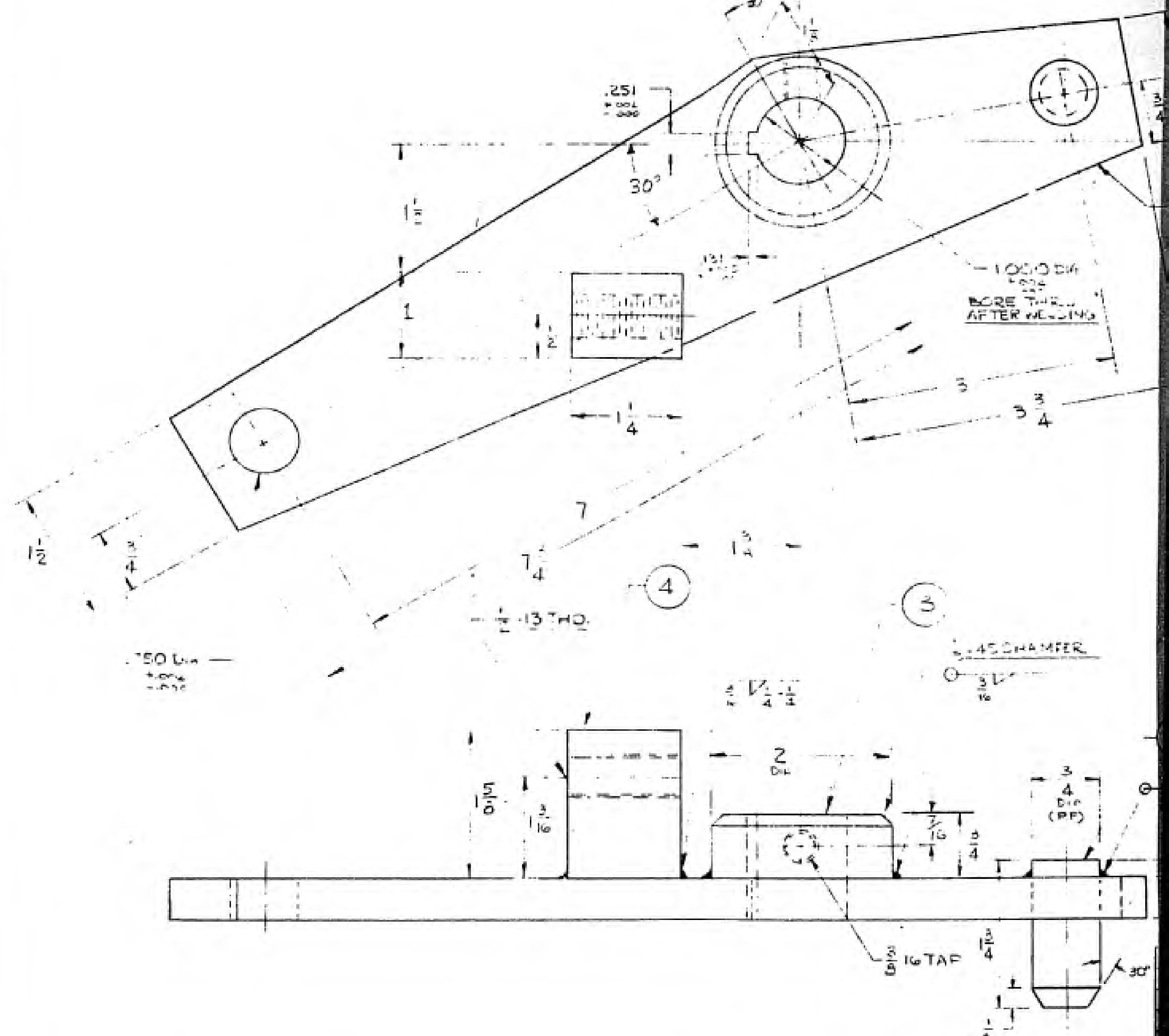
F.P.D.I.
- LAYOUT -
SUB FRAME
RELEASE MEC.

CURTISS-WRIGHT CORP.
PRINCETON DIVISION
PRINCETON, N.J. U.S.A.

NUCLEAR RAD DEPT.

E700280

FIG 3-4?



UNLESS OTHERWISE SPECIFIED

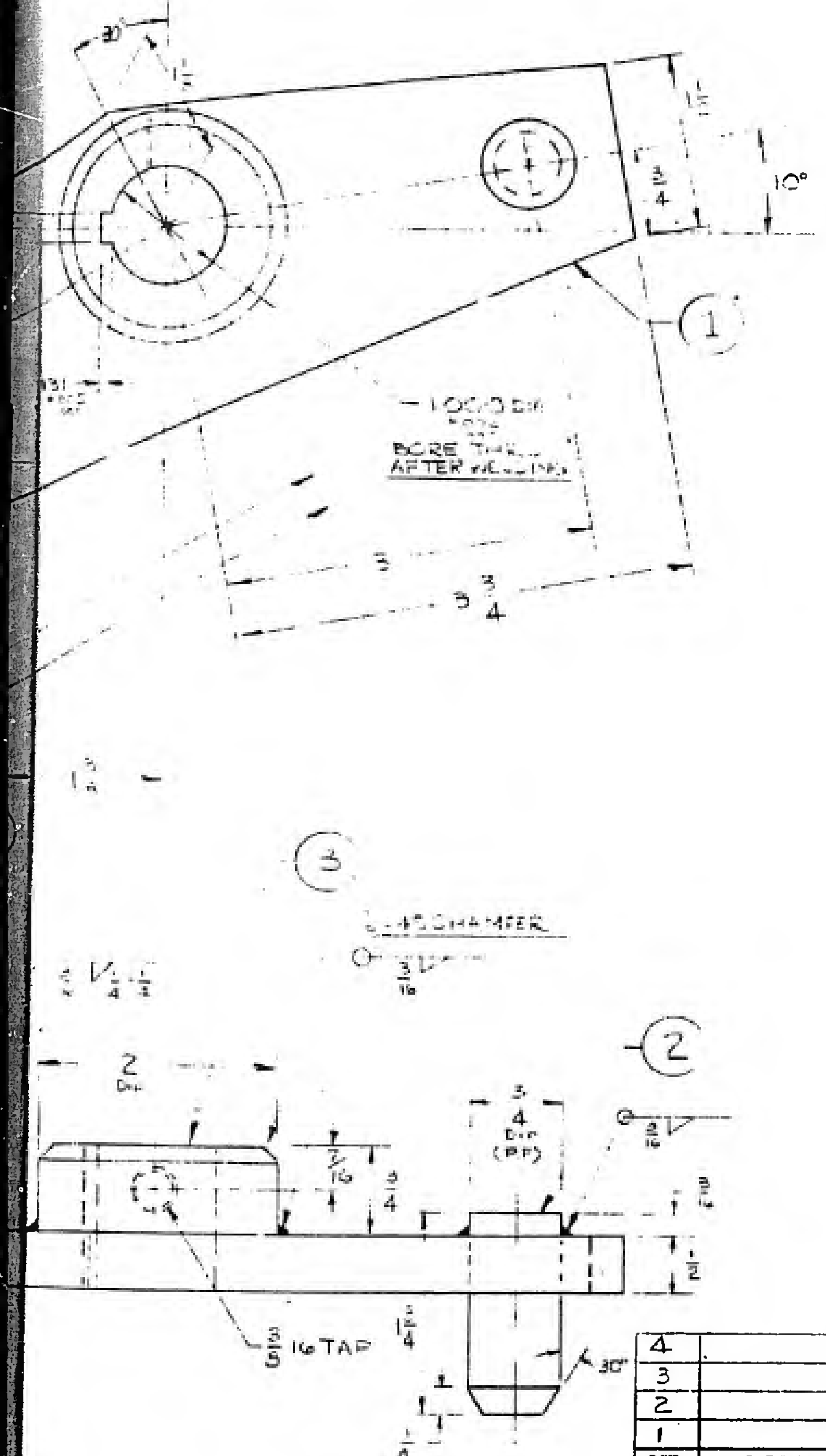
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACT. ± 1/64 CASTING ± 1/16
DECIMAL ± .005 FORGING ± 1/16
ANGULAR ± 1°

SPECIFICATION:

HEAT TREAT:

FINISH: NITRIC ACID PASSIVATE

Fig 3-23



C-700265

DET.	PART NO.	REQ'D	DESCRIPTION	MAT'L & SIZE	MAT'L SPEC.
4		1	BAR	1 x 1 1/4 x 1 5/8	STN. STL. # 302
3		1	BAR	2" DIA. x 3/4	STN. STL. BAR # 303
2		1	BAR	3/4 DIA. x 1 3/4 LG.	STN. STL. BAR # 303
1		1	PLATE	1/2 x 2 3/4 x 11 5/8	STN. STL. PL. # 302

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACT. ± 1/64 CASTING ± 1/16
DECIMAL ± .005 FORGING ± 1/16
ANGULAR ± 1°

SPECIFICATION:

HEAT TREAT:

FINISH: NITRIC ACID PASSIVATE

	NAME	DATE
DRAWN	[illegible]	7-25-60
CHECKED	RG	12-28-60
APPV'D		
ENG. APP'L		

TITLE: LEVER - RELEASE MECH 2

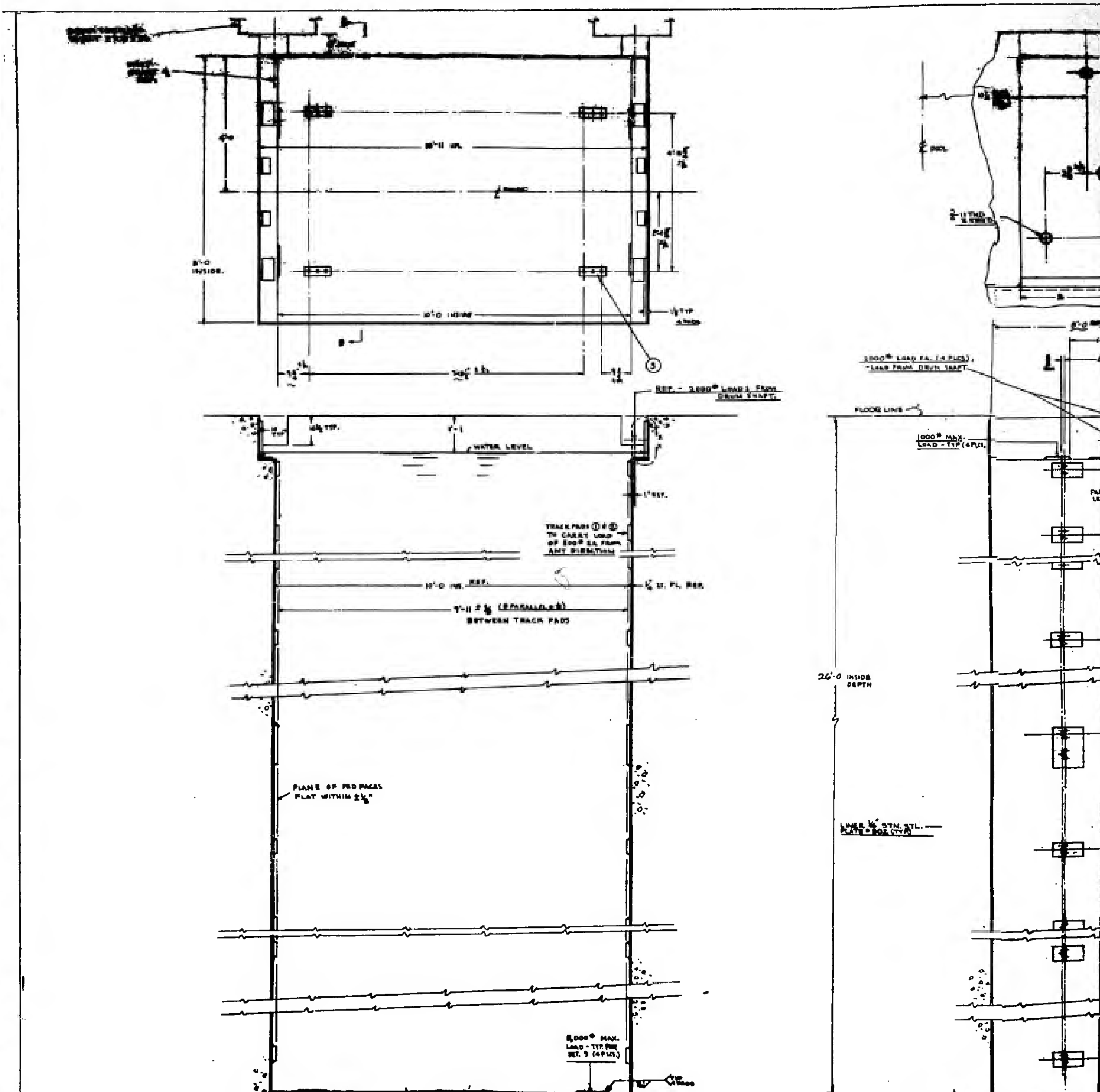
2 REQ'D. PER UNIT

SCALE FULL Fig 3-23

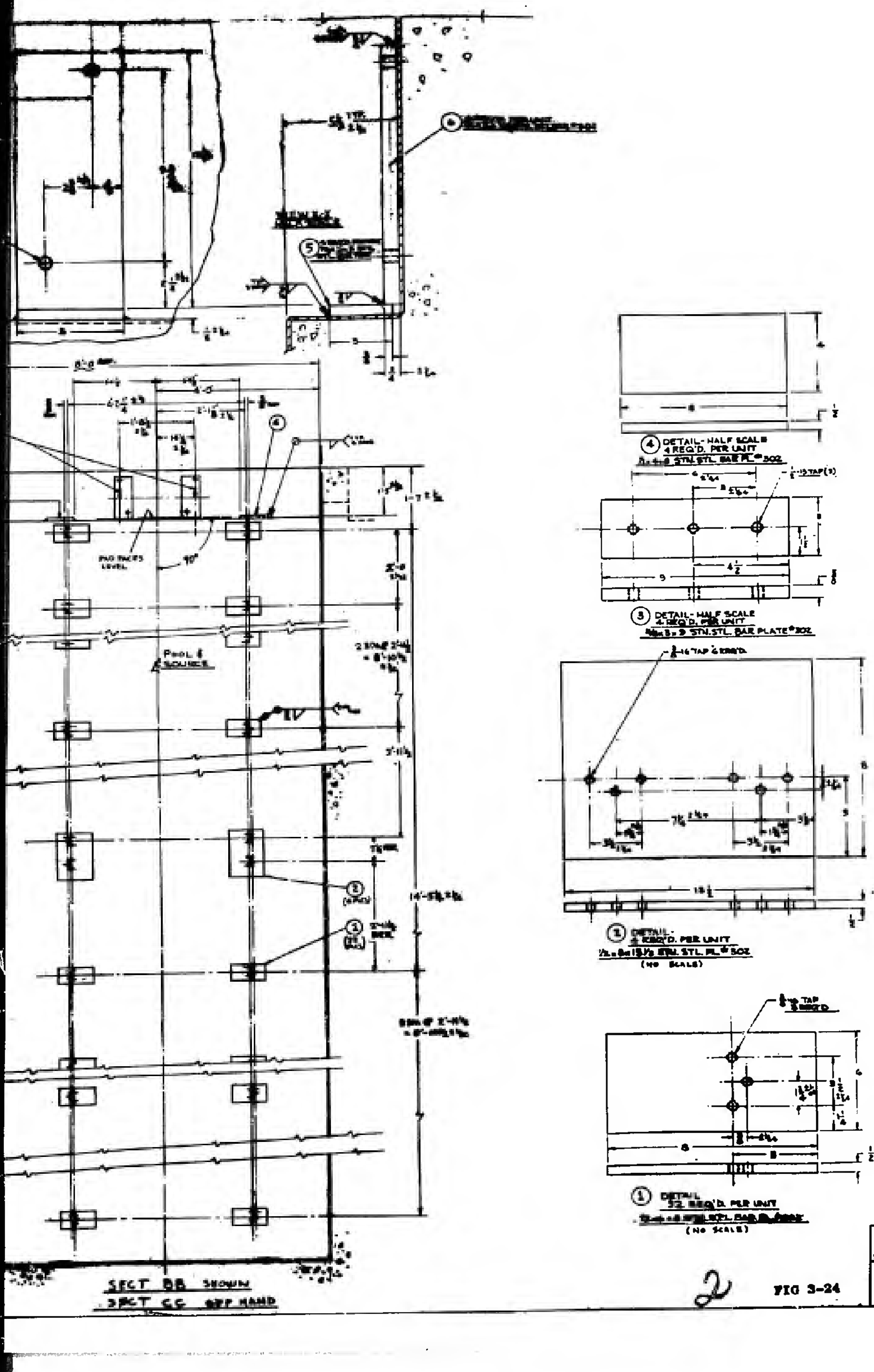
CURTISS-WRIGHT CORP.
PRINCETON DIVISION
PRINCETON, NEW JERSEY

C-700265

USED ON E700280


8'-0
INSIDE.
10'-0 INSIDE
WATER LEVEL
BETWEEN TRACK PADS
PLANE OF PAD FACES
FLAT WITHIN ±1/8"
FLOOR LINE
1000# MAX.
LOAD - TYP (4 PLS).
26'-0 INSIDE
DEPTH
8,000# MAX.

SECT AA



NOTES:

1. ¼" THICK STAINLESS STL. POOL LINER TO LINE ENTIRE INSIDE AREA. NO HOLES ARE PERMITTED THRU ANY PART OF LINER EXCEPT FOR WATER [illegible] ATING CONNECTIONS (WHICH WILL BE STAIN. STL. WELDED IN). WELDS IN LINER MAY NOT REDUCE THE ¼ THICKNESS
2. LINER MUST BE COMPLETELY ANCHORED IN CONCRETE POOL STRUCTURE AND BE SUPPORTED & ANCHORED DIRECTLY IN BACK OF PADS TO SUSTAIN LOADS SPECIFIED.
3. UNLESS OTHERWISE NOTED TOLERANCES FOR POOL LINER TO BE ±⅛". TOL. FOR PAD HOLE LOC. AS NOTED. LINER TO BE SQUARE & TRUE WITHIN ±⅛" LINER, PAD FACES, & PAD HOLE ℄S TO BE PLUMB WITHIN ±⅛, OVER THE 2[illegible] OF DEPTH. FOR PAD DETAILS ① THRU ⑥ TOL. TO BE [illegible] UNLESS OTHERWISE GIVEN.

SEE NOTE 3

D.R. [illegible]

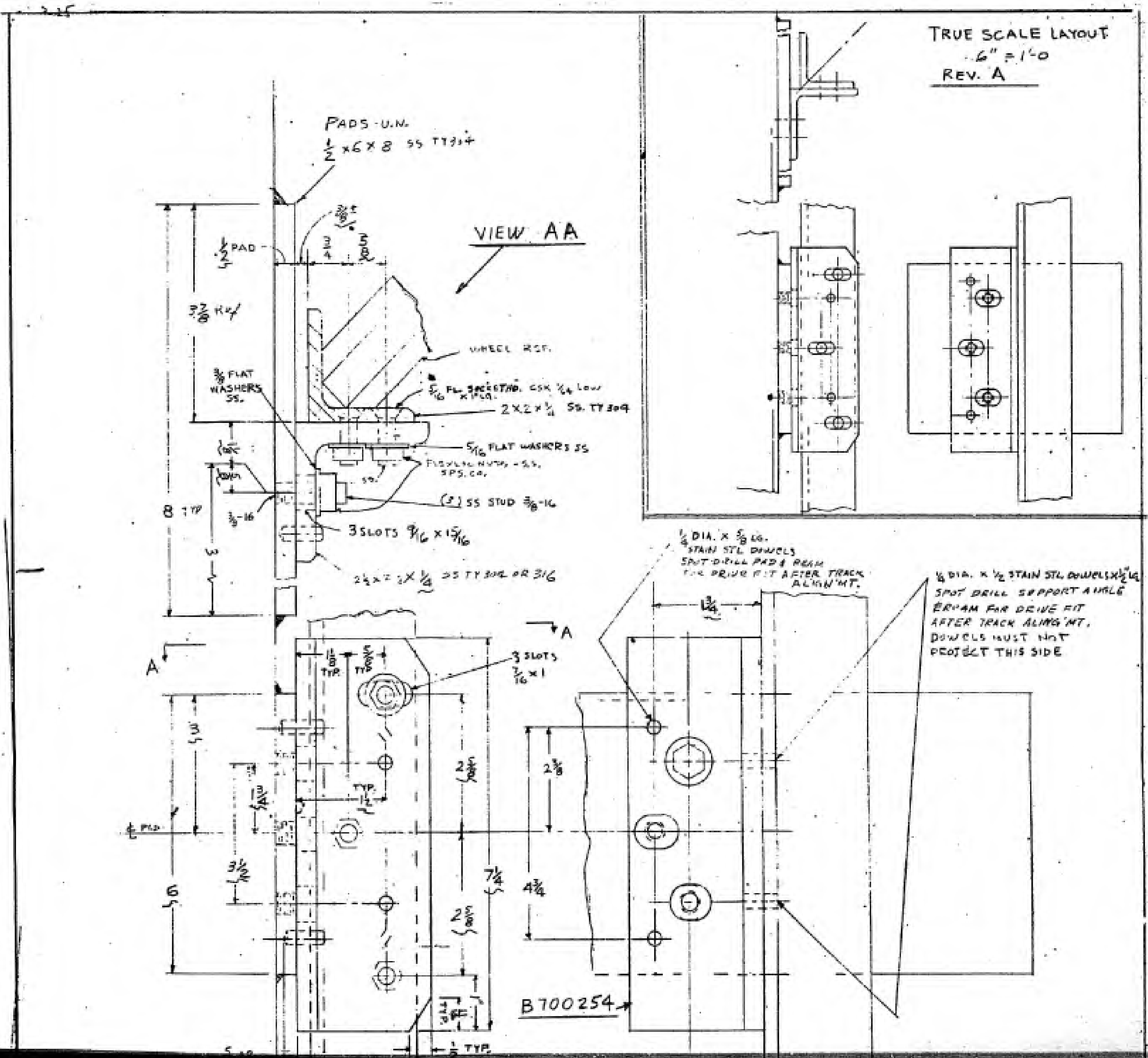
F.P.D.I.

SOURCE POOL LINER REQUIREMENTS

E-700250

2

FIG 3-24


TRUE SCALE LAYOUT
6" = 1'-0
REV. A
VIEW AA
PADS-U.N.
1/2 x 6 x 8 SS TT304
WHEEL REF.
3/8 FLAT WASHERS SS.
2 x 2 x 1/4 SS. TT 304
5/16 FLAT WASHERS SS
(3) SS STUD 3/8-16
3 SLOTS 9/16 x 1 5/16
8 TYP
3/8-16
3 SLOTS 7/16 x 1
1/4 DIA. x 5/8 LG. STAIN STL DOWELS SPOT-DRILL PAD & REAM FOR DRIVE FIT AFTER TRACK ALIGN'MT.
1/4 DIA. x 1/2 STAIN STL DOWELS x 1/2 LG SPOT DRILL SUPPORT ANGLE & REAM FOR DRIVE FIT AFTER TRACK ALING'MT. DOWELS MUST NOT PROJECT THIS SIDE
B700254

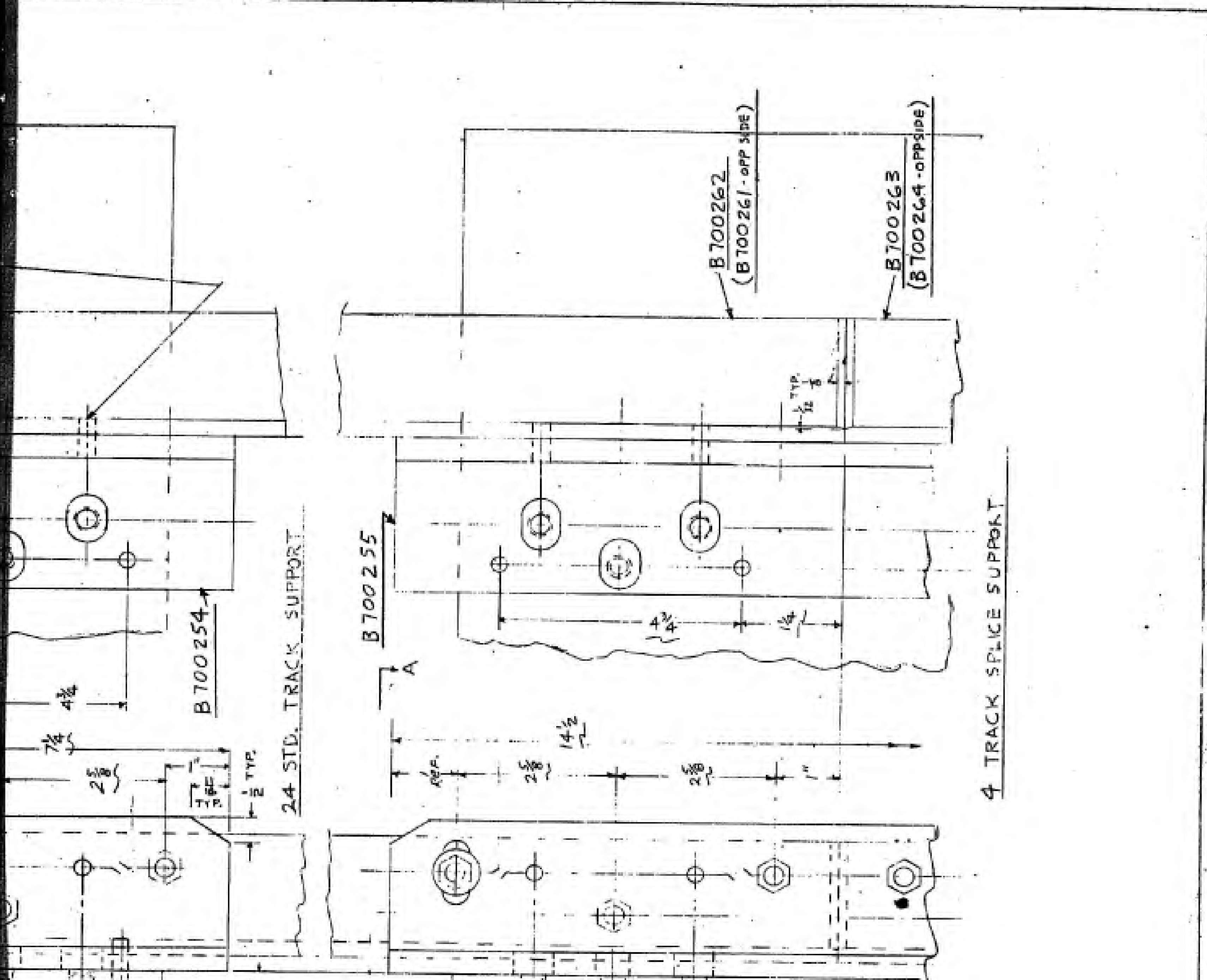

B700262
(B700261 - OPP SIDE)
B700263
(B700264 - OPPSIDE)
B700254
24 STD. TRACK SUPPORT
B700255
4 TRACK SPLICE SUPPORT
A
A
REF.
SYM ABT
℄ SPLICE
DRILL DEPTH
TYP.
REF: GEN'L ARRGT E700230
LAYOUT
TRACK SUPPORTS
SOURCE PLAT.
SCALE FULL SIZE
CURTISS-WRIGHT CORP.
PRINCETON DIVISION
PRINCETON, N.J. U.S.A.
NUCLEAR RAD. DEPT.
D700279

FIG 3-25

2

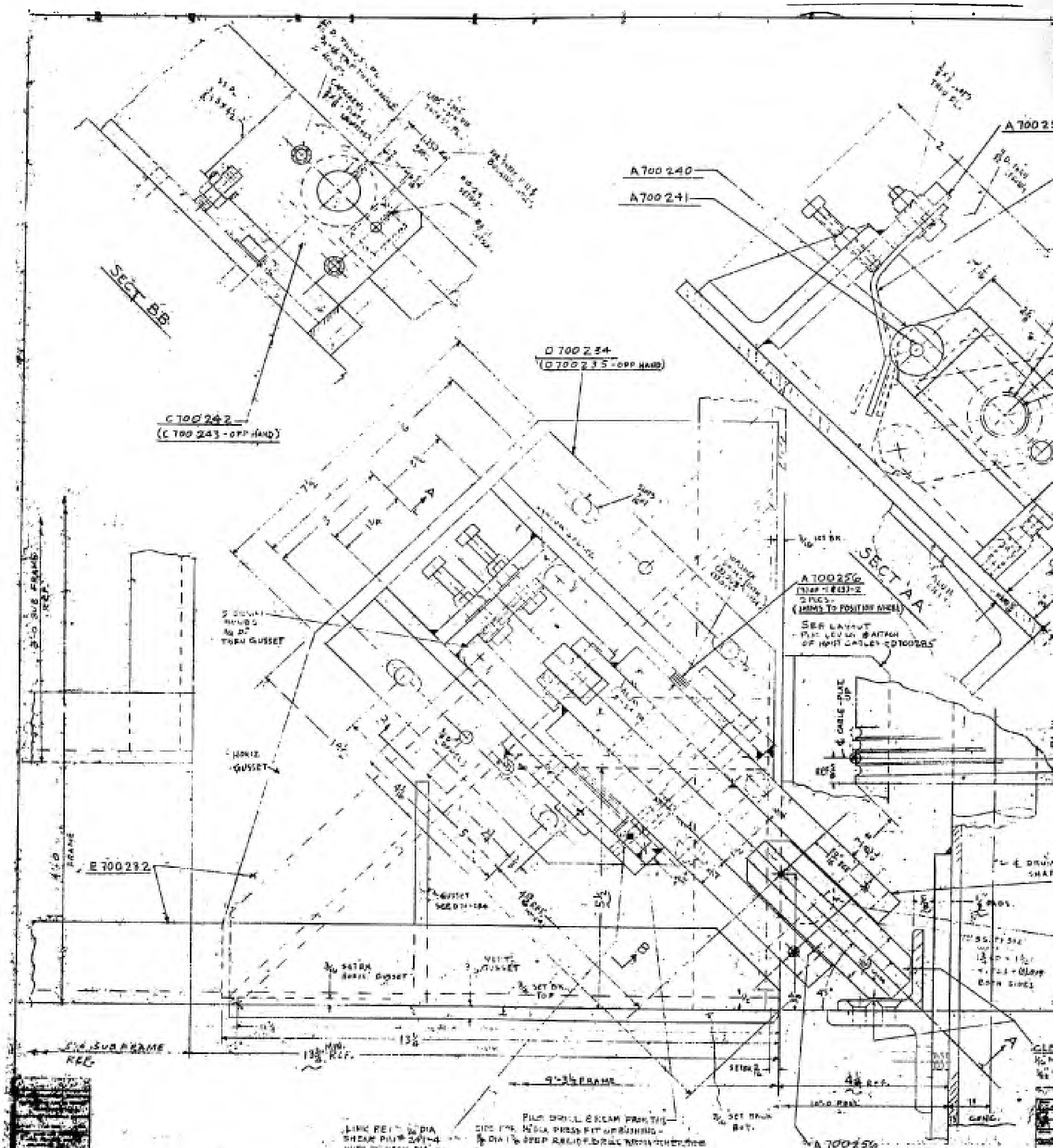

SECT BB
C 700 242
(C 700 243 - OPP HAND)
D 700 234
(D 700 235 - OPP HAND)
A 700 240
A 700 241
A 700 257
A 700 256
SECT 'A A'
SEE LAYOUT
E 700 232
9'-3½ FRAME
13⅞ REF.
5'-6 SUB FRAME REF.
A 700 256

FIG 3-26

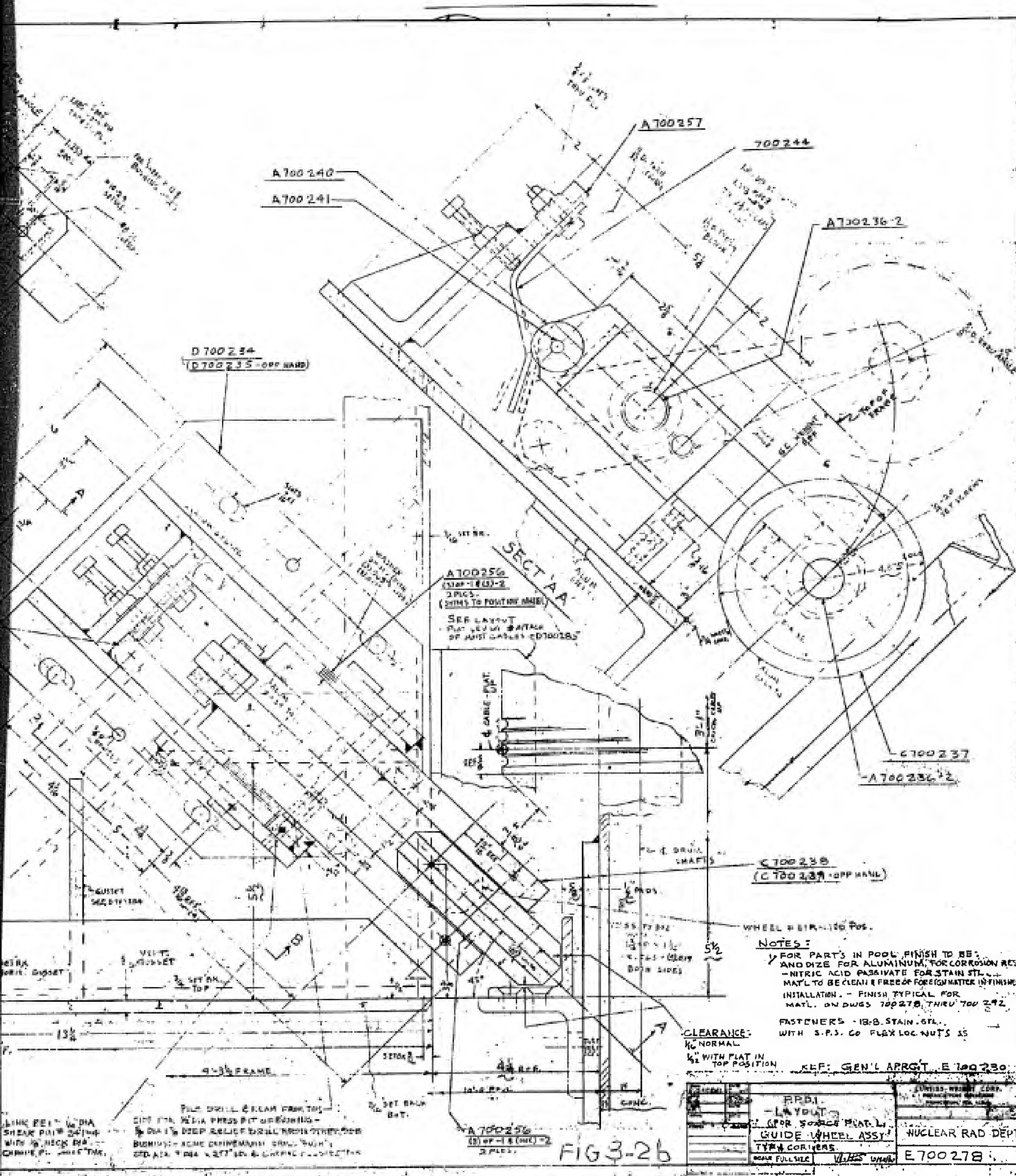
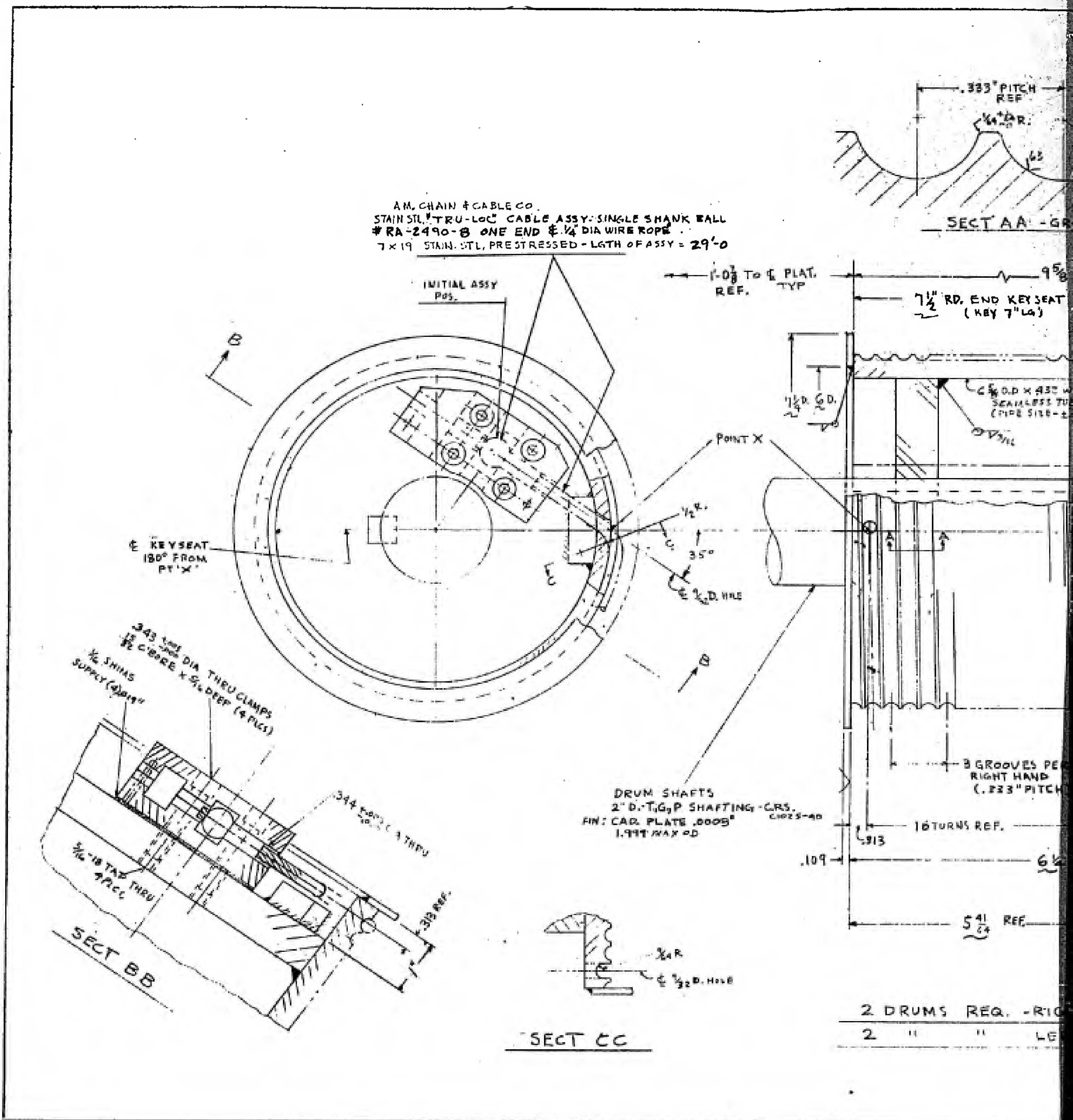

A 700 257
700 244
A 700 240
A 700 241
A 700 236-2
D 700 234
(D 700 235 - OPP HAND)
SECT 'A-A'
A 700 256
(3 PLCS - SHIMS TO POSITION WHEEL)
SEE LAYOUT
C 700 237
A 700 236-2
C 700 238
(C 700 239 - OPP HAND)
WHEEL # 6TR-130 POS.
NOTES:
1/ FOR PARTS IN POOL FINISH TO BE: ANODIZE FOR ALUMINUM, FOR CORROSION RES. - NITRIC ACID PASSIVATE FOR STAIN STL. MAT'L TO BE CLEAN & FREE OF FOREIGN MATTER IN FINISHED INSTALLATION. - FINISH TYPICAL FOR MATL. ON DWGS 700278 THRU 700 292
FASTENERS - 18-8 STAIN. STL. WITH S.P.S. Co FLEX LOC NUTS SS
CLEARANCE:
1/16 NORMAL
1/32 WITH FLAT IN TOP POSITION
REF: GEN'L ARRG'T E 700 230
9-3/4 FRAME
13-3/4
A 700 256
LAYOUT
GUIDE WHEEL ASSY
CURTISS-WRIGHT CORP.
NUCLEAR RAD DEPT.
SCALE FULL SIZE
E 700 278

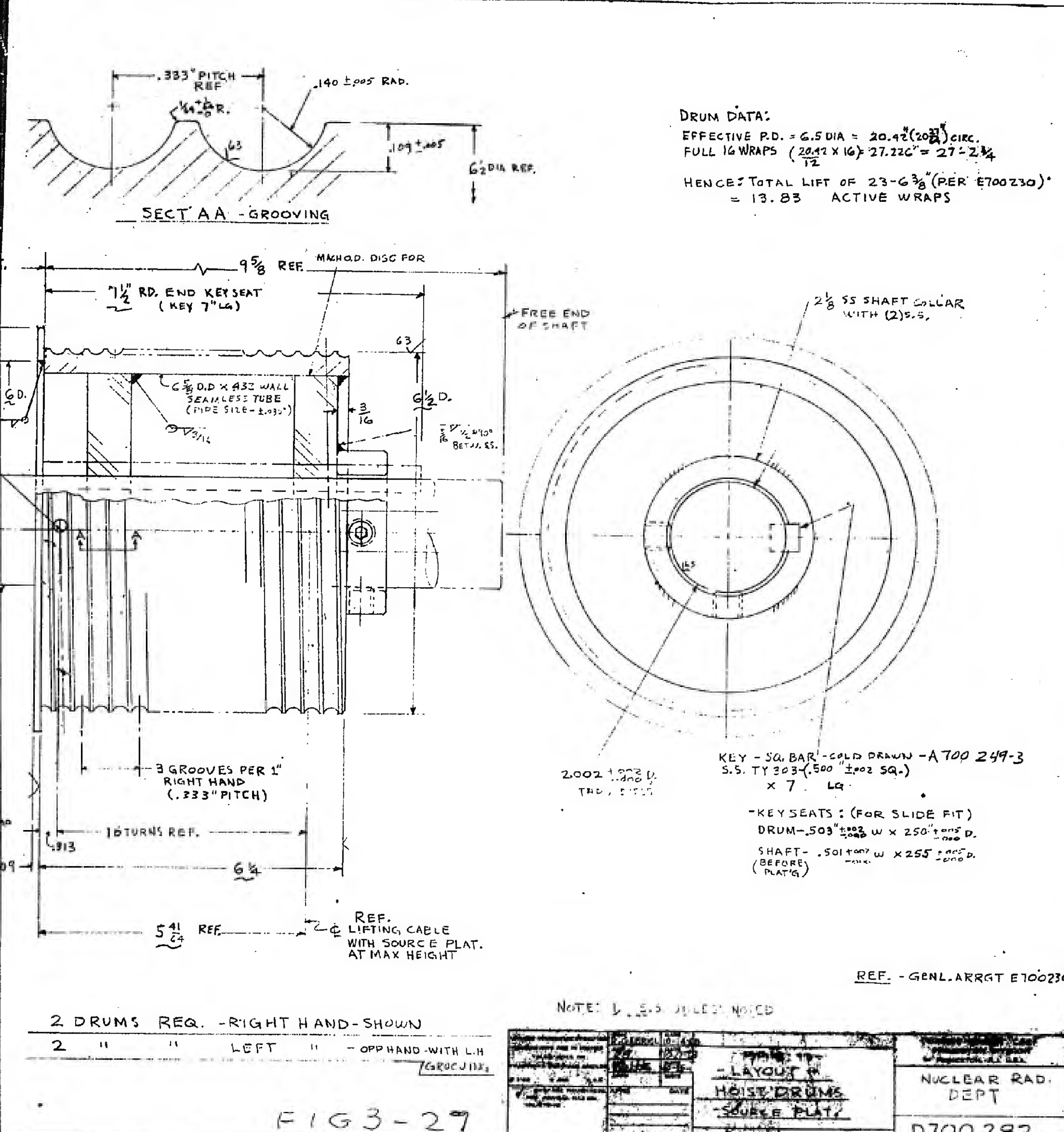
FIG 3-26

1

2

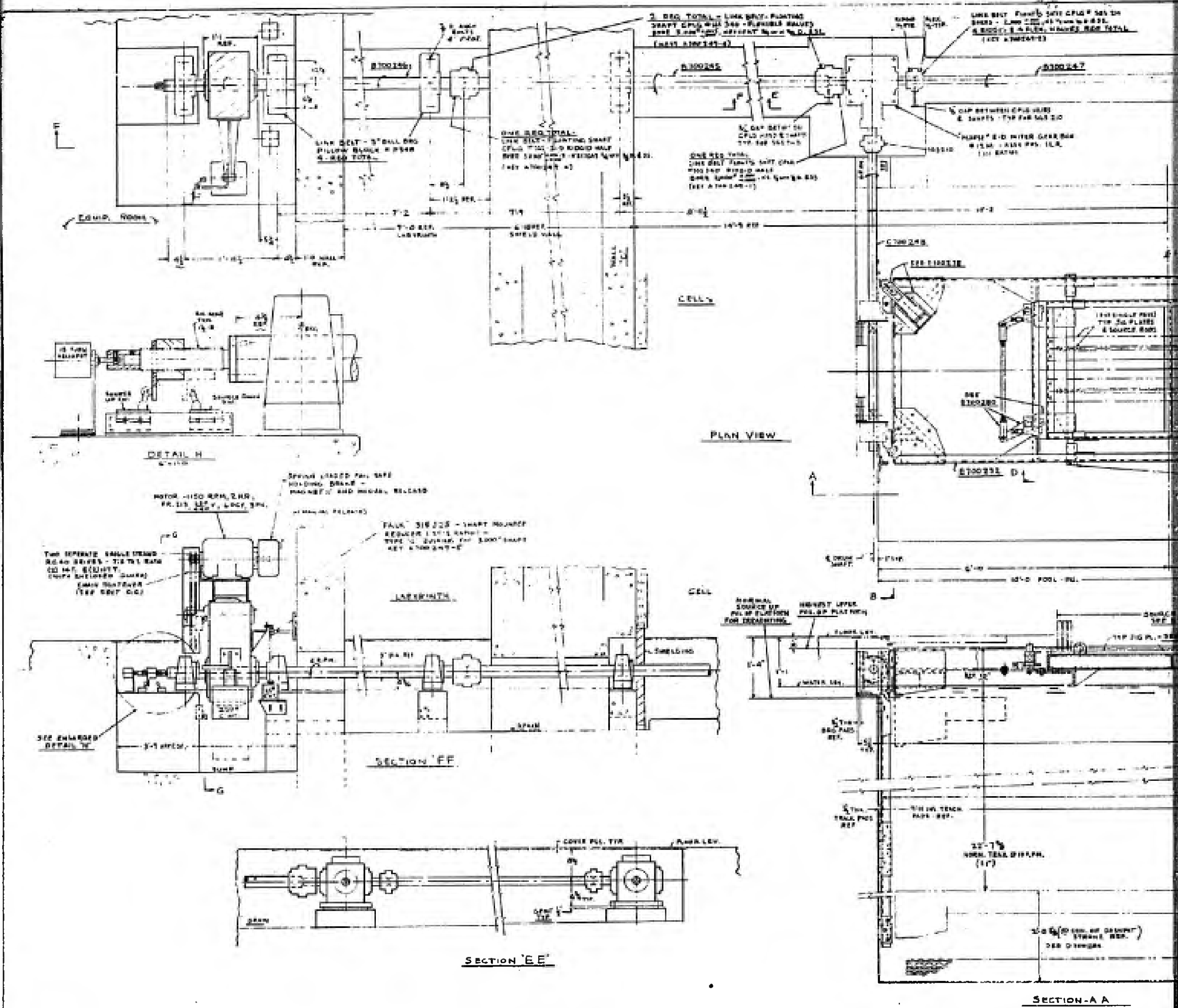


.333" PITCH REF
SECT AA
AM. CHAIN & CABLE CO.
STAIN STL. "TRU-LOC" CABLE ASSY - SINGLE SHANK BALL
RA-2490-B ONE END & 1/4" DIA WIRE ROPE
7 x 19 STAIN. STL, PRESTRESSED - LGTH OF ASSY = 29'-0
INITIAL ASSY POS.
1'-0 7/8 TO ℄ PLAT. REF. TYP
7 1/2" RD. END KEYSEAT (KEY 7" LG)
POINT X
℄ KEYSEAT 180° FROM PT 'X'
1/2 R.
35°
DRUM SHAFTS
2" D. - T.G.P SHAFTING - C.R.S.
FIN: CAD. PLATE .0005"
1.999 MAX OD
3 GROOVES PER
RIGHT HAND
(.333" PITCH
16 TURNS REF.
.313
.109
5 41/64 REF.
SECT BB
SECT CC
2 DRUMS REQ. - RI
2 " " LE



.333" PITCH REF
.140 ±.005 RAD.
.109 ±.005
6½ DIA REF.
SECT AA - GROOVING
DRUM DATA:
EFFECTIVE P.D. = 6.5 DIA = 20.42"(20 27/64) CIRC.
FULL 16 WRAPS (20.42/12 x 16) = 27.226' = 27'-2¾
HENCE: TOTAL LIFT OF 23-6⅜"(PER E700230) = 13.83 ACTIVE WRAPS
9⅝ REF.
MACH O.D. DISC FOR
7½" RD. END KEYSEAT (KEY 7"LG)
FREE END OF SHAFT
6⅝ O.D x .432 WALL SEAMLESS TUBE (PIPE SIZE-±.030")
6½ D.
3/16
BETW. SS.
2⅛ SS SHAFT COLLAR WITH (2) S.S.
3 GROOVES PER 1" RIGHT HAND (.333" PITCH)
16 TURNS REF.
.913
6¼
5 41/64 REF.
REF. ℄ LIFTING CABLE WITH SOURCE PLAT. AT MAX HEIGHT
2.002 D.
KEY - SQ. BAR - COLD DRAWN - A700 249-3
S.S. TY 303-(.500" ±.002 SQ.)
x 7 LG
-KEYSEATS: (FOR SLIDE FIT)
DRUM-.503" W x .250" D.
SHAFT- .501 W x .255 D. (BEFORE PLAT'G)
REF. - GENL. ARRGT E700230
NOTE:
2 DRUMS REQ. - RIGHT HAND - SHOWN
2 " " LEFT " - OPP HAND - WITH L.H GROOVING
- LAYOUT OF HOIST DRUMS - SOURCE PLAT.
NUCLEAR RAD. DEPT
D700 282

FIG 3-27


EQUIP. ROOM
CELL
PLAN VIEW
DETAIL H
LABYRINTH
CELL
SECTION 'FF'
SECTION 'EE'
SECTION-A A

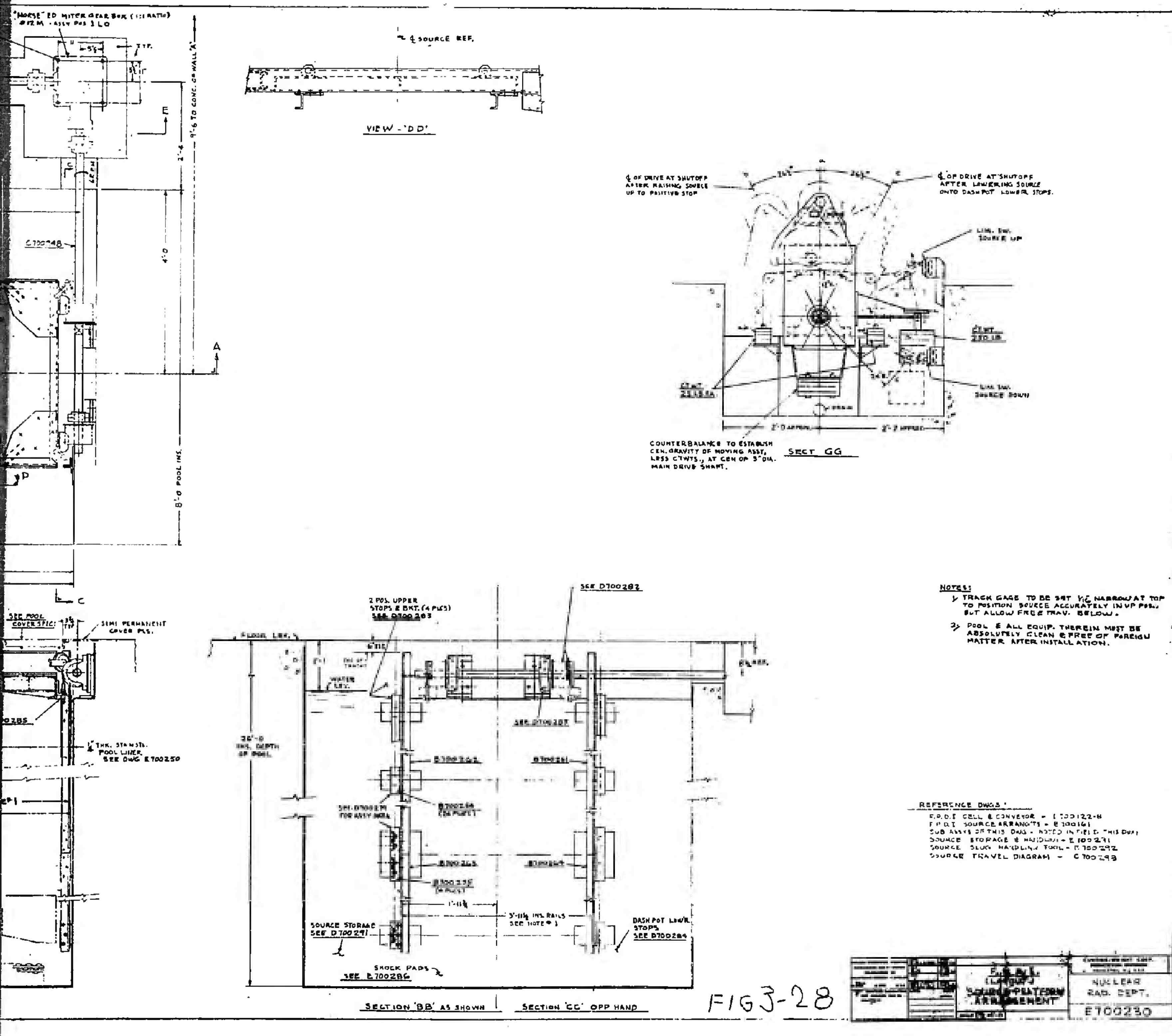
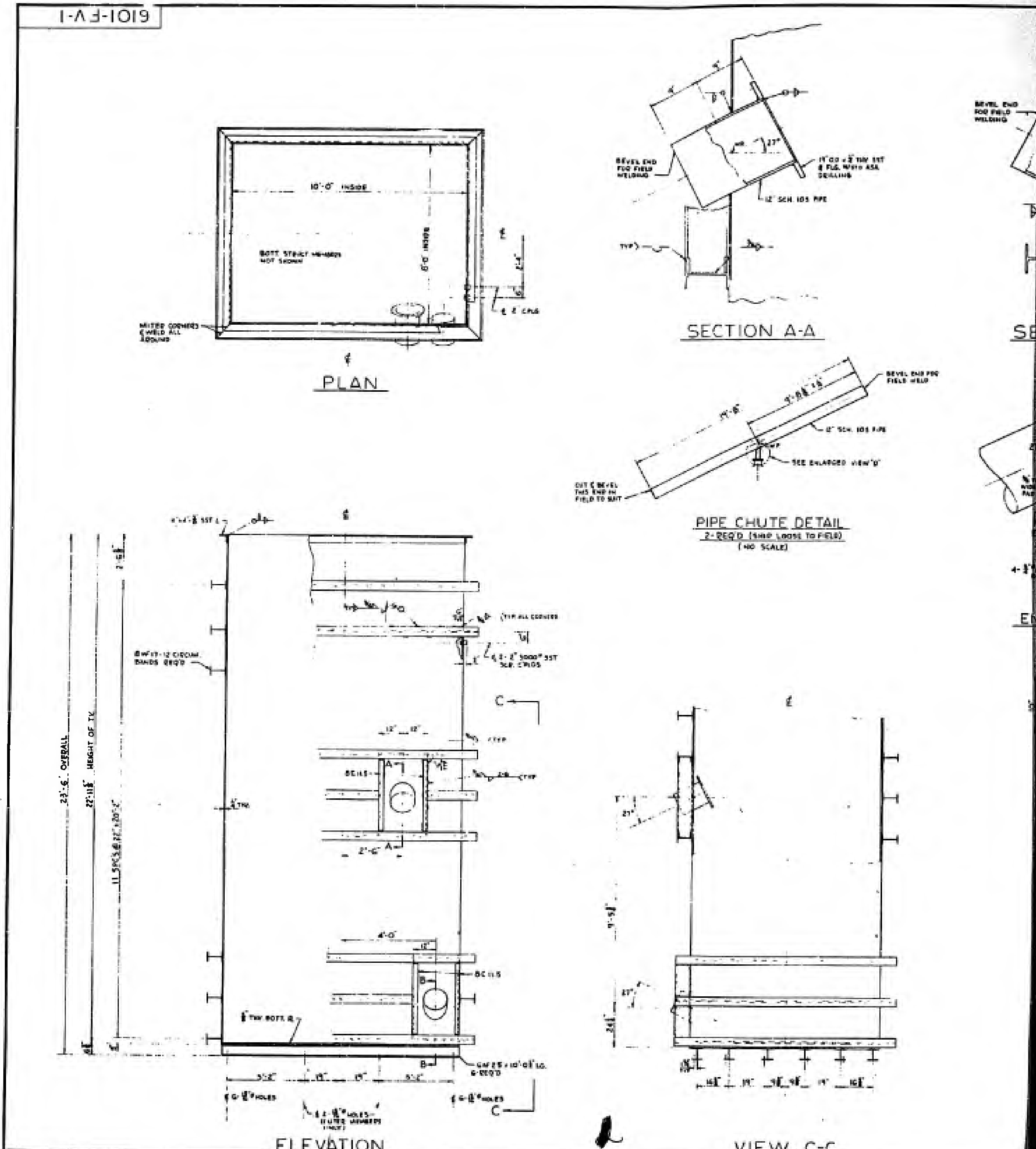

VIEW - 'DD'
SECT GG
COUNTERBALANCE TO ESTABLISH CEN. GRAVITY OF MOVING ASSY., LESS CTWTS., AT CEN OF 5" DIA. MAIN DRIVE SHAFT.
SECTION 'BB' AS SHOWN
SECTION 'CC' OPP HAND
NOTES:
1) TRACK GAGE TO BE SET 1/16 NARROW AT TOP TO POSITION SOURCE ACCURATELY IN UP POS. BUT ALLOW FREE TRAV. BELOW.
2) POOL & ALL EQUIP. THEREIN MUST BE ABSOLUTELY CLEAN & FREE OF FOREIGN MATTER AFTER INSTALLATION.
REFERENCE DWGS:
SOURCE TRAVEL DIAGRAM - C700293
NUCLEAR RAD. DEPT.
E700230

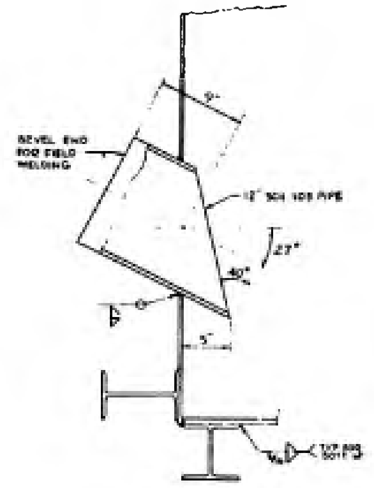
FIG 3-28

2

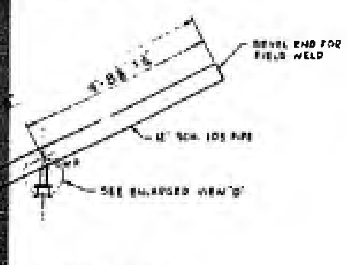


10'-0" INSIDE
BOTT. STIFF'S NOT SHOWN
MITRED CORNERS & WELD ALL AROUND
PLAN
BEVEL END FOR FIELD WELDING
12" SCH. 10S PIPE
SECTION A-A
BEVEL END FOR FIELD WELD
12" SCH. 10S PIPE
SEE ENLARGED VIEW "D"
CUT & BEVEL THIS END IN FIELD TO SUIT
PIPE CHUTE DETAIL
2-REQ'D (SHIP LOOSE TO FIELD)
(NO SCALE)
23'-6" OVERALL
C
A
B
ELEVATION
VIEW C-C

ION A-A



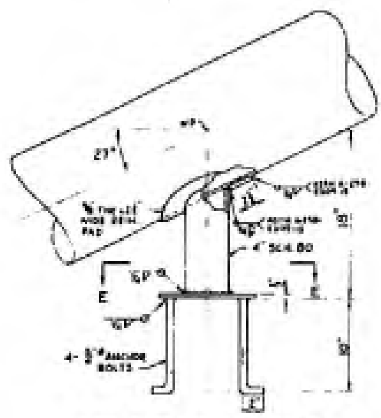
SECTION B-B



CHUTE DETAIL

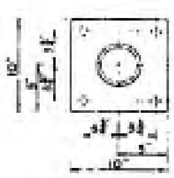
D (SHIP LOOSE TO FIELD)

(NO SCALE)

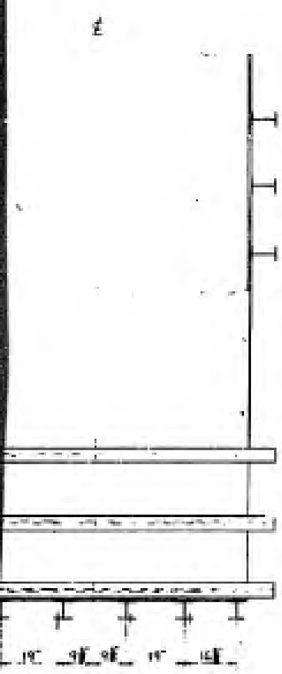


ENLARGED VIEW 'D'

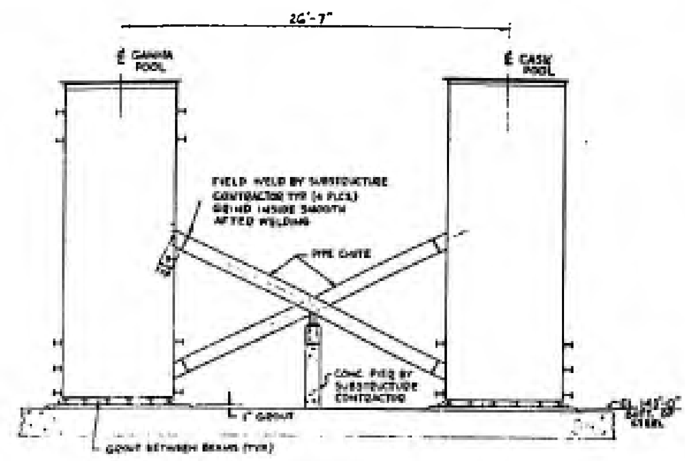
SCALE 1½"=1'-0"



SECTION E-E



VIEW C-C



ELEVATION LOOKING WEST

SCALE: ¼"=1'-0"

NOTE

1) PIPE CHUTES ARE TO BE TEMPORARILY BRACED & FIELD WELDED TO TANKS PRIOR TO PLACING OF CONCRETE PIER AT CENTER SUPPORT POINT BRACING IS NOT TO BE REMOVED UNTIL PIER HAS SET

2) CHUTES ARE TO BE HYDRO. TESTED IN FIELD TO 20 PSIG & FIELD WELDS ARE TO BE DYE PENETRANT TESTED

NOTES:

1. VESSELS SHALL BE FABRICATED IN ACCORDANCE WITH THE REQUIREMENTS OF SECT. VIII OF THE ASME UNFIRED PRESSURE VESSEL CODE, LATEST EDITION & SECT IX OF THE ASME CODE FOR WELDING QUALIFICATIONS, & ANI SPEC. Nº 6101-V-1. CODE STAMP IS NOT REQ'D

2. MATERIAL

VESSEL SHELL (SIDES & BOTTOM)	—	CLAD PLATE PER ASTM A-264 BASE METAL — ASTM A-285 GR.C 10% CLADDING METAL ON INSIDE FACE — ASTM A-240 TYPE 304 SST
ANGLE RIM	—	ASTM A-240 TYPE 304 SST
STRUCTURAL SHAPES	—	ASTM A-7 (EXCEPT AS NOTED)
PIPE (CHUTE)	—	ASTM A-312 TYPE 304 SST S'MLS
FORGING	—	ASTM A-312 TYPE 304 SST
PIPE SUPPORT	—	ASTM A-53 SMLS
SUPPORT PLATE	—	ASTM A-283 OR A-7
SUPPORT ANCHORS	—	ASTM A-107
SST FIELD WELDS	—	ASTM A-298-CLASS E 308-15
PADS (INTERNAL)	—	ASTM A-240 TYPE 304 SST

3. DESIGN DATA

DESIGN PRESS. & TEMP.	—	10.5 PSIG @ 250°F
JOINT EFFICIENCY	—	0.85
CORROSION ALLOWANCE	—	INTERNAL - NONE, EXTERNAL - BITUMASTIC COATING
RADIOGRAPHING	—	SPOT EXAMINATION PER CODE
HYDROSTATIC TEST	—	FULL OF WATER

4. PAINT — BITUMASTIC COATING ON ALL EXTERIOR CARBON STEEL SURFACES IN ACCORDANCE WITH ANI SPEC Nº 6101-V-1

5. INSPECTION — ANI

6. VESSELS SHALL BE SHOP FABRICATED, TESTED, AND SHIPPED IN ONE PIECE TO THE FIELD FOR INSTALLATION BY SUBSTRUCTURE CONTRACTOR.

7. PIPE SUPPORTS SHALL BE ATTACHED TO CHUTES IN SHOP AND ASSEMBLIES SHIPPED LOOSE TO FIELD FOR INSTALLATION BY SUBSTRUCTURE CONTRACTOR.

8. ALL LONGITUDINALL SEAMS TO BE MIN OF 6" FROM CORNERS.

9. WEIGHTS & CAPACITY:

	GAMMA POOL	CASK POOL
ERECTION	20,000#	20,000#
OPERATING	143,000#	165,000#
TEST	135,000#	135,000#
CAPACITY	13,800 GAL.	13,800 GAL.

10. REFERENCE DWGS:

GAMMA POOL — 6101-FV-2

PRINTED
APR 13 1961
A.N.

ISSUE	DESCRIPTION	CHKD.	DISP.	CORR.	APPR.
5					
4					
3					
2					
1	ORIGINAL ISSUE	[illegible]	[illegible]	[illegible]	[illegible]

CASK POOL

QUARTERMASTER RADIATION LABORATORY
FOR
U. S. ATOMIC ENERGY COMMISSION
ASSOCIATED NUCLEONICS, INC.
A SUBSIDIARY OF
STONE & WEBSTER ENGINEERING CORPORATION

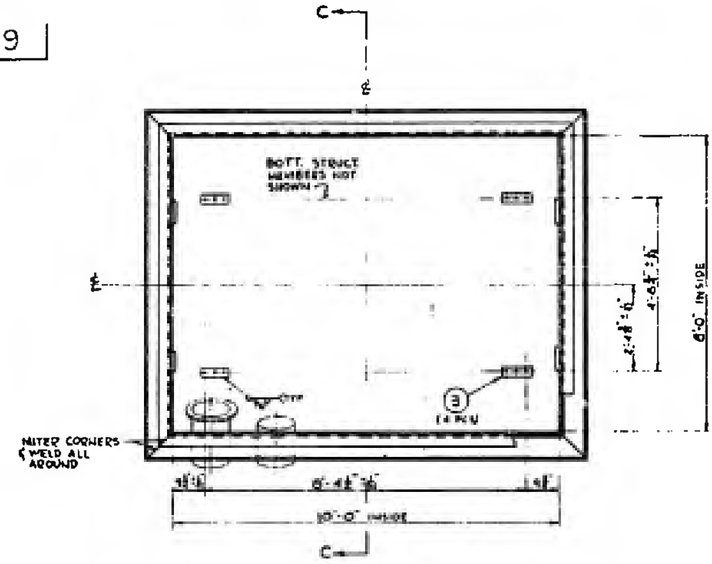
SCALE: ¼"=1'-0" & NOTED

DRAWING NUMBER 6101-FV-1

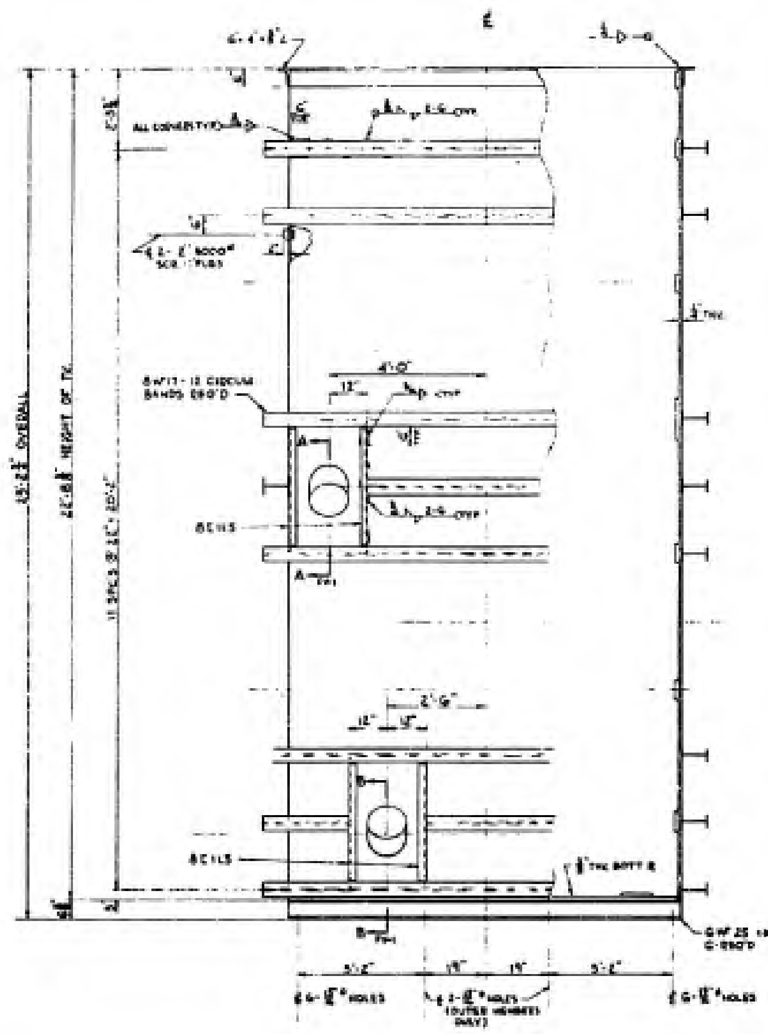
Fig 3-29

2

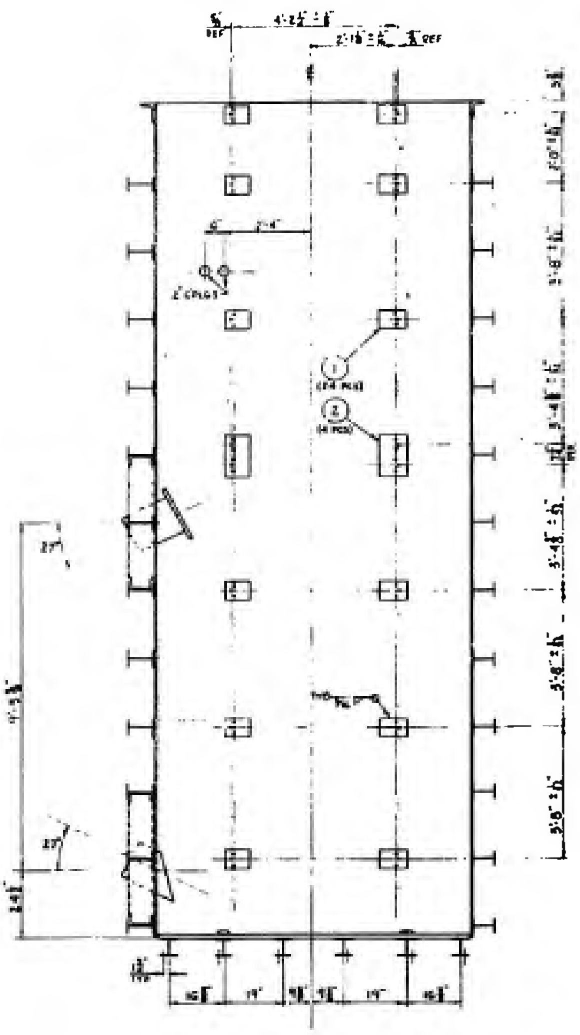
6101-FV-2



PLAN

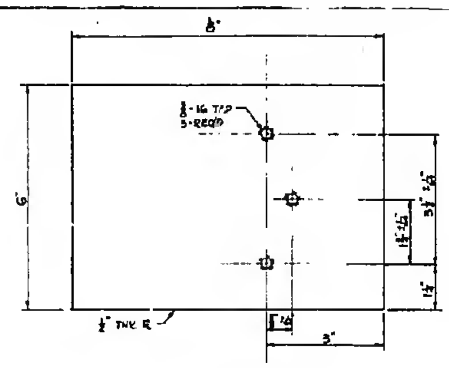


ELEVATION

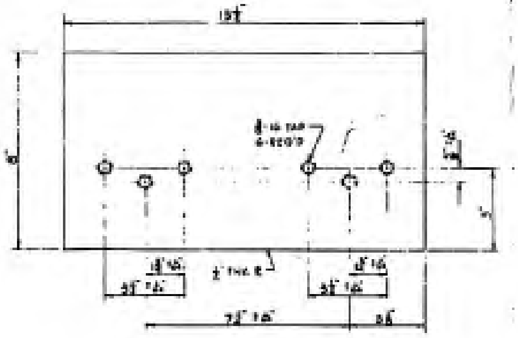


SECTION C-C

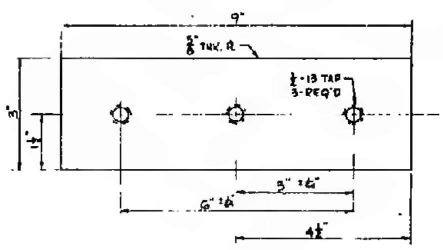
NOTE: DO NOT DRILL THROUGH TANK WALLS.



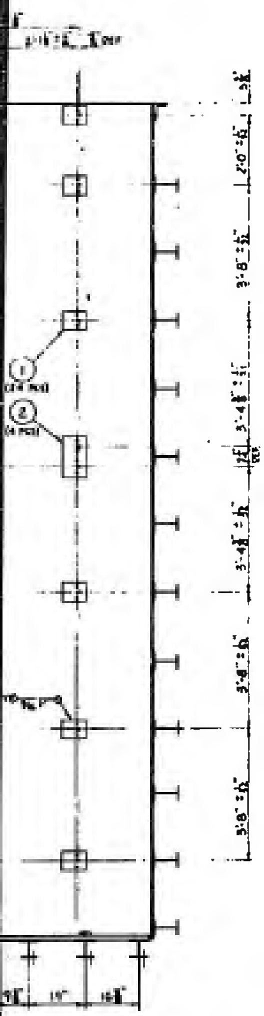
DETAIL ①
24-REQ'D MAT'L-TP #304 SST R
SCALE: 6"=1'-0"



DETAIL ②
4-REQ'D MAT'L-TP #304 SST R
(NO SCALE)



DETAIL ③
4-REQ'D MAT'L-TP #304 SST R
SCALE: 6"=1'-0"



ON C-C

LL THROUGH

FOR DESIGN DATA, MAT'L NOT INDICATED, SECTIONS A-A & B-B & GENERAL NOTES SEE DWG. FV-1.

2

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APR 13 1951
A. N.

Fig 3-30

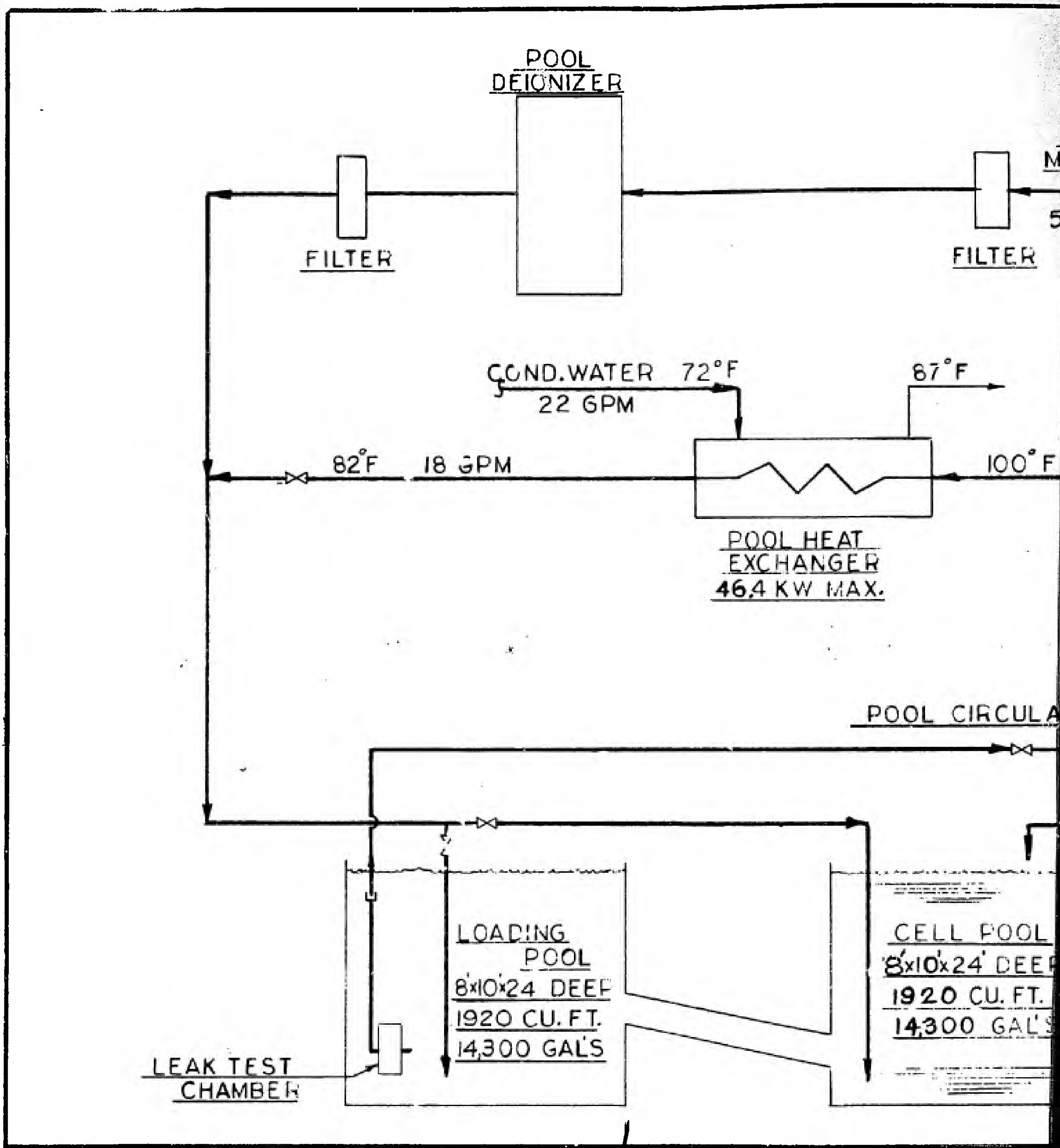
ISSUE	DESCRIPTION	CHKD.	INSP.	CORR.	APPR.
5					
4					
3					
2					
1	ORIGINAL ISSUE				

GAMMA POOL

QUARTERMASTER RADIATION LABORATORY
FOR
U. S. ATOMIC ENERGY COMMISSION
ASSOCIATED NUCLEONICS, INC.
A SUBSIDIARY OF
STONE & WEBSTER ENGINEERING CORPORATION

SCALE: ½"=1'-0" & NOTED

DRAWING NUMBER 6101-FV-2


POOL DEIONIZER
FILTER
FILTER
COND. WATER 72°F
22 GPM
67°F
82°F 18 GPM
100°F
POOL HEAT EXCHANGER
46.4 KW MAX.
POOL CIRCULA
LOADING POOL
8×10×24 DEEP
1920 CU. FT.
14,300 GAL'S
CELL POOL
8'×10'×24' DEEP
1920 CU. FT.
14,300 GAL'S
LEAK TEST CHAMBER

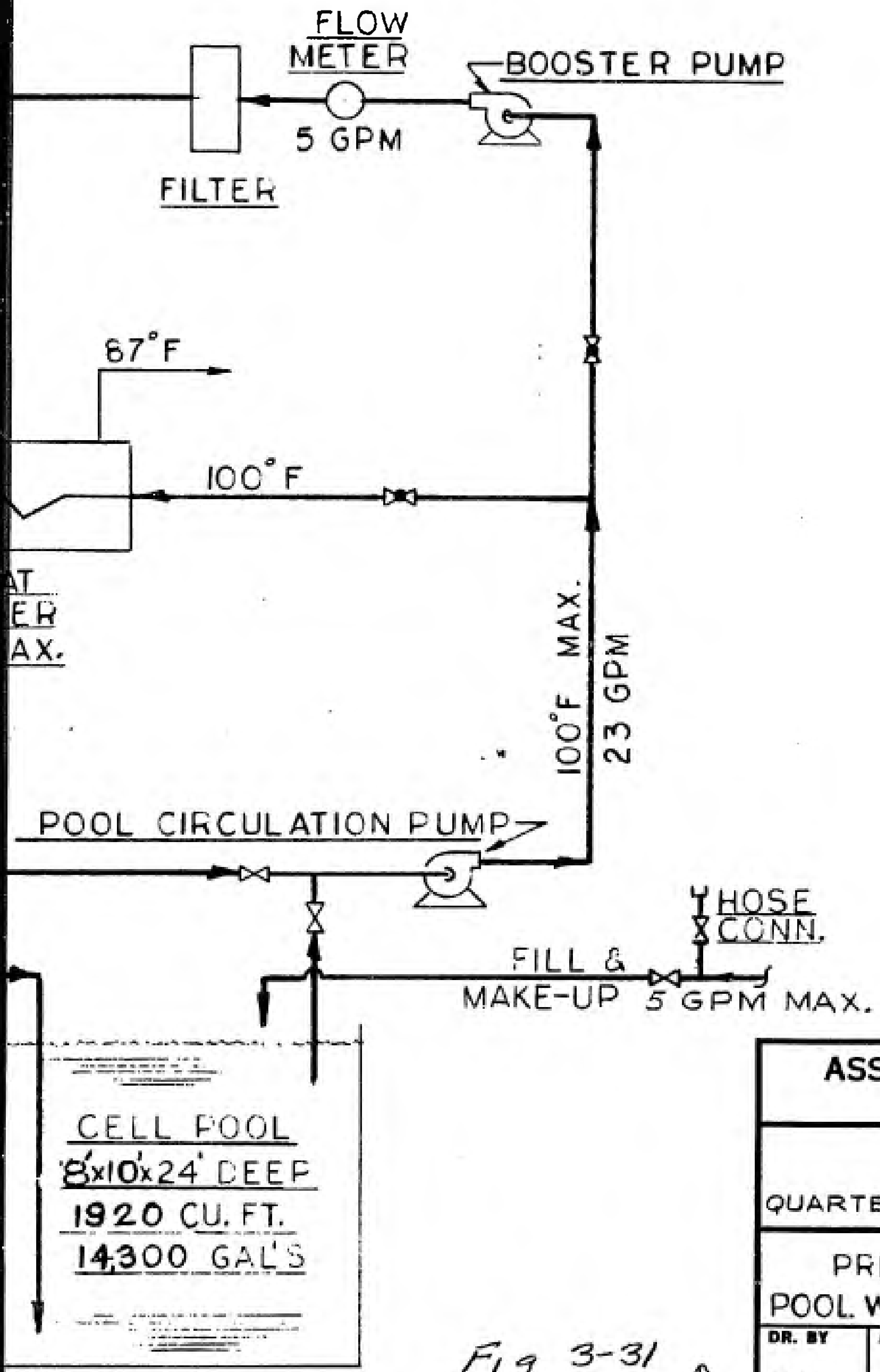


Fig 3-31

2

ASSOCIATED NUCLEONICS, INC.
GARDEN CITY, NEW YORK

PREPARED FOR
U.S.A.E.C.
QUARTERMASTER RADIATION LABORATORY

PRELIMINARY DIAGRAM
POOL WATER TREATMENT SYSTEM

DR. BY	APP. BY	SCALE	W. O. NO.	DRAWING NO.	REV.
DATE	DATE	NONE	6101	SK-2	