

IF-300 REDUNDANT YOKE

NUREG-0612 EVALUATION

Revision 1

General Electric Company

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## 1.0 INTRODUCTION

Generic Technical Activity Task A-36 was established by the Nuclear Regulatory Commission (NRC) staff to review licensing criteria and the adequacy of measures in effect at operating nuclear power plants for handling heavy loads under critical load situations. NUREG-0612 reports the results and recommendations of Task 36. The general guidelines published in NUREG-0612 include the design, manufacture, operation, and maintenance of special lifting devices such as the IF-300 redundant yoke.

This document summarizes an evaluation of the IF-300 redundant yoke for compliance to the guidelines of NUREG-0612.

## 2.0 NUREG-0612 GUIDELINES

The guidelines in NUREG-0612 which are related to special lifting devices such as the IF-300 redundant yoke are as follows:

5.1.1(4) Special lifting devices should satisfy the guidelines of ANSI N14.6-1978, "Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 pounds (4500 kg) or More for Nuclear Materials." This standard should apply to all special lifting devices which carry heavy loads in areas as defined above. For operating plants certain inspections and load tests may be accepted in lieu of certain material requirements in the standard. In addition, the stress design factor stated in Section 3.2.1.1 of ANSI N14.6 should be based on the combined maximum static and dynamic loads that could be imparted on the handling device based on characteristics of the crane which will be used. This is in lieu of the guideline in Section 3.2.1.1 of ANSI N14.6 which bases the stress design factor on only the weight (static load) of the load and of the intervening components of the special handling device.

### 5.1.6 (1 ) Lifting Devices:

- (a) Special lifting devices that are used for heavy loads in the area where the crane is to be upgraded should meet ANSI N14.6 1978, "Standard For Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More For Nuclear Materials."

as specified in Section 5.1.1(4) of this report except that the handling device should also comply with Section 6 of ANSI N14.6-1978. If only a single lifting device is provided instead of dual devices, the special lifting device should have twice the design safety factor as required to satisfy the guidelines of Section 5.1.1(4). However, loads that have been evaluated and shown to satisfy the evaluation criteria of Section 5.1 need not have lifting devices that also comply with Section 6 of ANSI N14.6.

5.1.6 (3) Interfacing lift points such as lifting lugs or cask trunnions should also meet one of the following for heavy loads handled in the area where the crane is to be upgraded unless the effects of a drop of the particular load have been evaluated and shown to satisfy the evaluation criteria of Section 5.1:

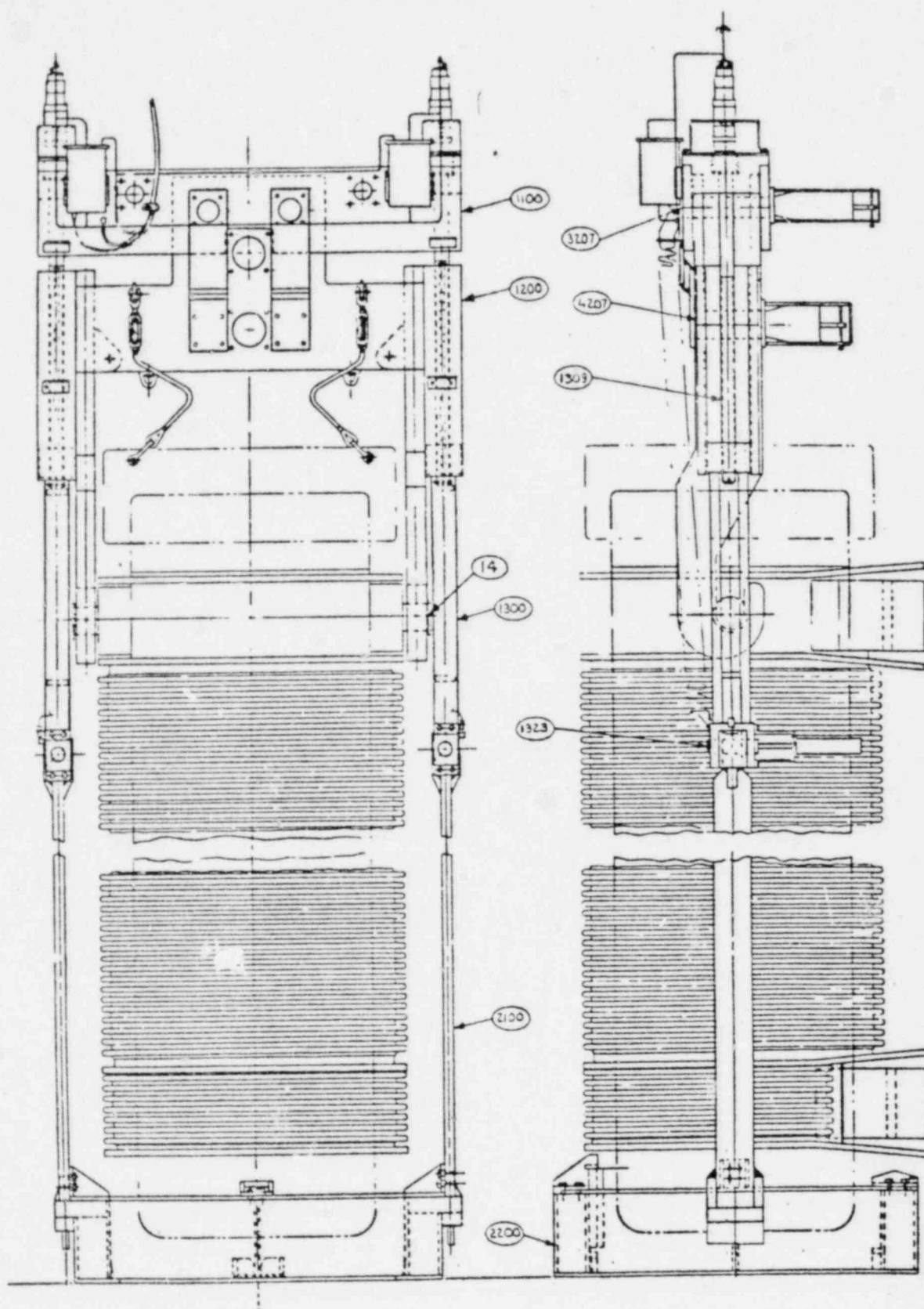
- (a) Provide redundancy or duality such that a single lift point failure will not result in uncontrolled lowering of the load; lift points should have a design safety factor with respect to ultimate strength of five (5) times the maximum combined concurrent static and dynamic load after taking the single lift point failure.

### 3.0 IF-300 REDUNDANT YOKE

#### 3.1 Description

As referenced in Amendment 33 of the FSAR for the Cooper station, the IF-300 redundant yoke system is an active/passive one where the redundant portions become load bearing only when there is a failure of a primary lifting component. Three IF-300 redundant yokes have been built and put into operation after the Cooper FSAR submittal. The IF-300 redundant yoke final design and stress factors are slightly different from those described in the Cooper FSAR, but the general design and operating principles have not changed. Figure 1 is a general arrangement drawing of the IF-300 cask with its redundant yoke. The redundant yoke system is designed so that upon failure of a primary load-bearing component there is effectively a nil-displacement load transfer to the secondary components.

FIGURE 1



IF 300  
REDUNDANT YOKE

### 3.2 Crane Hook/Yoke Interface

Redundant crane hook designs provide for at least two separate load-paths from the cask yoke to the crane bottom block. One design uses links or cables which by-pass the crane hook. Other designs utilize some form of coaxial load path such that a single hook assembly provides the necessary degree of redundancy. The IF-300 yoke concept is compatible with either redundant interface. The yoke cross-member accommodates both the Whiting and P&H redundant hooks and has other attachment points for alternative rigging methods.

Referring to Figure 1, the primary connection to the redundant hook is through a six-inch diameter high strength pin. Hook connection to the secondary system yoke is via two 4-1/4" diameter high strength pins. The two smaller pins would also be used if the secondary load-path used links or cables. The two major crane manufacturers, P&H and Whiting, provide redundancy through a central hole engagement and two sister hook palm engagements. P&H's central hole passes through both load-path hooks while Whiting's is a separate component passing through and extending below the sister hook. These arrangements are similar in principle; however, mating with the Whiting unit requires a somewhat different pin spacing than the P&H version due to the greater distance between sister hook palms and the central lifting hole. The yoke cross-member can accept either hook by moving the pin assembly.

### 3.2 Lifting Yoke

The lifting yoke is in fact two yokes, one active and one passive.

#### 3.2.1 Active Yoke (Primary)

The active yoke consists of two fixed arms, a cross-member structure and a pin assembly. As discussed in 3.1, the 6" diameter pin engages the central hole of the reactor or fuel building crane. The pin has a retracting mechanism for ease in engagement. The deep J-hooks on the yoke arms engage the cask trunnions which are mounted between the upper pair of impact rings (see Figure 1). This same yoke design (without the secondary structure) is used for those applications where redundancy is not required.

### 3.3.2 Passive Yoke (Secondary)

The passive or secondary yoke consists of two vertically movable arms, a cross-member structure, two 4-1/4" diameter pins, two power screws and two air cylinder assemblies. As described in 3.1, the 4-1/4" diameter pins engage the secondary load-path of the building redundant hook. The movable arms retract to provide clearance during cask uprighting operations. In the extended position the arms engage the cask-mounted lower arm assembly via the two 3" diameter air operated pins. Arm movement is achieved through a travelling block on an air motor driven power screw. This power screw is also a load bearing member (on failure of the active yoke). The nil-backlash feature is achieved through air-motor reversal following cask/yoke pin engagement.

### 3.4 Cask-Mounted Lower Arm Assembly

The stainless steel lower arm assembly consists of a circular cradle and two vertical arms (see Figure 1). The cask is first uprighted and then placed in and secured to the cradle. The length of the arms are such that the upper end pin engagement blocks fall well above the cask center-of-gravity when in the vertical position. The lower arm assembly is secured to the cask by two clamps which act on the cask lower end fins. Stability of this component when under load is achieved by the encircling cradle engagement and the wide base at the clamping plane.

### 3.5 Materials and Fabrication

#### 3.5.1 Materials

The following table lists the major components of the redundant system and their materials of construction.

TABLE 1

Component	Material
Primary Yoke	
6" dia. pin	AISI 4340 steel
cross members	ASTM A-514 steel
arms	ASTM A-514 steel
Cask Body	
trunnion blocks	Type 304N st. steel
trunnion block pins	AISI 4340 steel
structural rings	Type 216 st. steel



Table 1 (cont'd)

Component	Material
Secondary Yoke	
4-1/4" dia. pins	AISI 4340 steel
cross members	ASTM A-514 steel
travelling arm	Type 304 st. steel
travelling block	Type 304 st. steel
power screw	Nitronic-60 st. steel
fixed top block	ASTM A-181 G2 steel
traveling block insert	Nitronic-32
block guides	ASTM A-283 grade D steel
lower pin	AISI 4340
lower pin fork	Type 304 st. steel
travelling block key	Type 304 st. steel
travelling block stop	A-283 grade D steel
Lower Arm Assembly	
pin engagement blocks	Type 304 st. steel
support arms	Type 304 st. steel
mounting bolts	A 325 Type 1 steel
clamps	Type 304 st. steel
support cradle	Type 304 st. steel

### 3.5.2 Fabrication

Structure fabrication is performed to standards consistent with the service intended. All material for load bearing members is certified as to chemical and physical properties. In addition, all stressed members are ultrasonically inspected for internal defects. Welding is performed by qualified personnel to approved procedures. Weldor and weld qualifications are done in accordance with Section IX of the ASME Code.

Stainless steel welds are inspected using liquid penetrant techniques. Structural steel welds are inspected using liquid penetrant or magnetic particle methods. All fabrication documentation is collected and retained for the lifetime of the equipment. Any repairs or modifications to the equipment are performed and inspected to standards comparable to those of the original fabrication. A visual and functional inspection of the system is performed on at least an annual basis.



### 3.6 Redundancy

The IF-300 cask redundant lifting device, by virtue of the primary yoke/secondary yoke system, is capable of sustaining the complete and instantaneous failure of any single stressed member of the primary system without a subsequent dropping of the load.

There are two failure points of the primary lifting yoke which characterize all possible yoke failure modes. These points are (1) the 6" diameter hook/yoke interface pin; or (2) one of the two cask/yoke interface connections, either the J-hook, trunnion or trunnion pin. The first case places the entire cask load on the secondary system. The second case has one side of the cask supported by the primary yoke pin and one leg while the other side is supported by the secondary yoke and leg.

All structures and attachment points are coplanar so that there is no rotation of the cask upon primary lifting device failure. There is essentially no slack in the system, thus there is load transfer but no impact loading due to cask downward movement. In fact, it would be a rather unique failure, namely one with no yielding or displacement, to shift the complete load to the secondary system.

### 3.7 System Operation

Upon arrival of the IF-300 cask at the reactor site the transport vehicle is placed under the redundant crane (Figure 2 shows the IF-300 cask mounted on its railcar). The screened enclosures are rolled back and the upper cooling ducts extended outboard thus providing total access to the cask from above. The tiedown pins are removed and the two cask lifting trunnions are installed.

The redundant yoke with the movable arms in the retracted position is mounted on the building crane hook (described in 2.1 above) and the controls are connected. This assembly is then joined to the cask by engaging the cask lifting trunnion with the deep J-hooks of the primary yoke. The cask is then rotated to the vertical position and removed from the transport skid and placed into

the lower arm assembly where it is secured. At this point in time the movable arms are extended downward until they contact the engagement blocks at the top of the lower arm assembly. Once contact is made the air driven pins are inserted thus locking the yoke to the lower structure. The system is now redundant and cask movement to the pool can occur.

Head nut removal prior to pool submersion is performed on the decontamination pad. There is sufficient room for this operation with the yoke in place; however, yoke removal at this point for static cask operations is acceptable as long as redundancy is reestablished prior to further lifting.

The cask is placed on the pool bottom pad for fuel loading. The air motor is used to establish removal clearance on the lower pins. This is done by driving the secondary arms downward. Retraction of the air-operated pins separates the secondary system from the cask. The movable arms are retracted and the primary yoke disengaged by a lowering and traversing operation, thus freeing the entire assembly from the cask. Head removal can be done using either slack cables suspended from the primary yoke cross-member or by employing a separate lifting device.

Following fuel loading and head replacement the above procedure is reversed for yoke reconnection. The primary yoke engages the cask trunnions. Then the secondary arms are extended and pinned to the lower arm assembly. Air motor reversal eliminates the slack, and cask removal from the pool can proceed.

Replacement of the decontaminated cask onto its transporter is also just the opposite of its removal. This involves retraction of the secondary pins and arms, removal of the cask from the lower arm assembly, placement of the cask into its pivot cradle and rotation to the horizontal position.

The use of a passive secondary system simplifies cask handling operations and equipment design. The size of the actuating equipment can be kept small because the loads involved are only the yoke components, not some fraction of the cask weight. The design is quite simple and the actuating components have been used extensively in underwater nuclear applications.

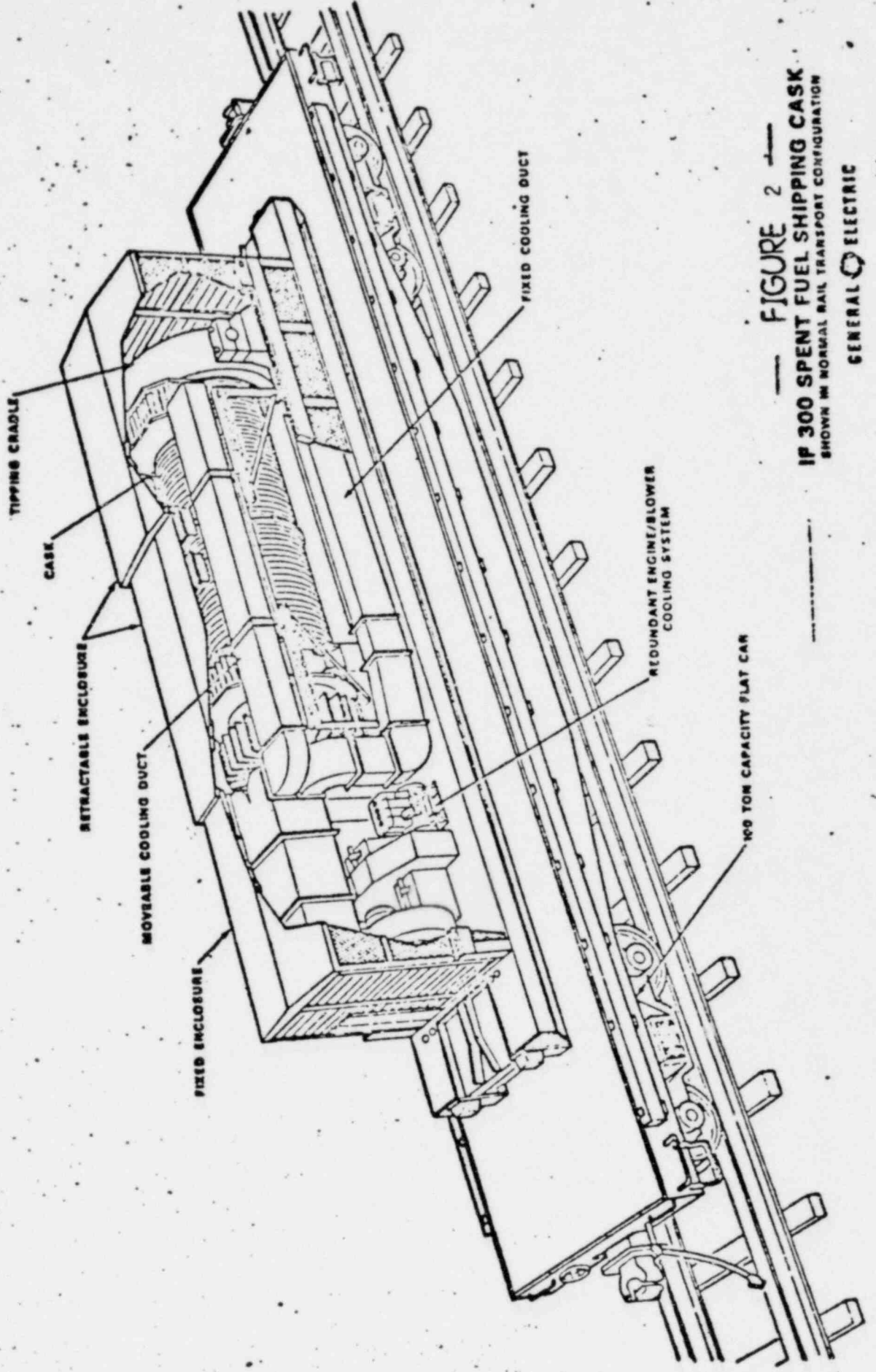


FIGURE 2  
IP 300 SPENT FUEL SHIPPING CASK  
SHOWN IN NORMAL RAIL TRANSPORT CONFIGURATION  
GENERAL ELECTRIC

### 3.8 Stress Analysis

The original design basis load for the IF-300 redundant yoke was such that three times the cask weight would not cause stresses exceeding yield in any yoke component. The safety factor of three was intended to include dynamic snatch load effects. Now however, NUREG-0612 requires a safety factor of three (on yield) on the sum of the static and dynamic yoke loads. For static loads of the same magnitude as of the crane capacity, the dynamic load is calculated per CMAA #70, paragraph 3.3.2.1.1.3 as follows:

$$d_f = .005 \times H_s \times W_s$$

where:  $d_f$  = dynamic load factor

$H_s$  = hoist speed (feet per minute)

$W_s$  = static weight of the load

For the IF-300 redundant yoke, the maximum crane hoist speed is 5 fpm, so that  $d_f = .025 W_s$ .

Therefore, the overall design stress factor (SF) for the redundant yoke becomes, per NUREG-0612:

$$SF = 3 (W_s + d_f)$$

$$SF = 3 (W_s + .025 W_s)$$

$$SF = 3.075 W_s \text{ (on yield)}$$

The original design basis for the IF-300 cask trunnion was also based on a factor of three times the cask weight. For this component, NUREG-0612 requires a safety factor of five, on ultimate strength, on the sum of the static and dynamic cask loads. This results in an overall design stress factor for the trunnions of:

$$SF = 5 (W_s + .025 W_s)$$

$$SF = 5.125 W_s \text{ (on ultimate)}$$

A summary of the maximum stresses in the yoke components and cask trunnions which are in the critical load line are presented in Table 1. The safety factors presented are based on the original design basis and NUREG-0612 requirements. In all cases the safety factor is greater than one and the yoke satisfies the NUREG-0612 design stress criteria.

TABLE 1  
IF-300 Redundant Yoke  
Stress Analysis Summary

6" PIN STRESS ANALYSIS - ITEM #4207, Figure 1

	Safety Factors <sup>+</sup>	
	<u>3.0 W<sub>s</sub><sup>*</sup></u>	<u>3.075 W<sub>s</sub></u>
Bending Stress	2.18	2.13
Shear Stress	7.59	7.40
Bearing Stress	6.41	6.25

4.25" PIN STRESS ANALYSIS - ITEM #3207, Figure 1

	Safety Factors	
	<u>3.0 W<sub>s</sub></u>	<u>3.075 W<sub>s</sub></u>
Bending Stress	1.09	1.06
Shear Stress	7.61	7.42
Bearing Stress	9.45	9.22

3.0" PIN STRESS ANALYSIS - ITEM #1323, Figure 1

	Safety Factors	
	<u>3.0 W<sub>s</sub></u>	<u>3.075 W<sub>s</sub></u>
Bending Stress	1.21	1.18
Shear Stress	4.05	3.95
Bearing Stress	7.68	7.49

UPPER ARM STRESS ANALYSIS - ITEM #1300, Figure 1

	Safety Factors	
	<u>3.0 W<sub>s</sub></u>	<u>3.075 W<sub>s</sub></u>
Nut Block Thread Shear Stress	3.28	3.20
Insert I.D. Thread Shear Stress	5.22	5.09
Tie Bar Tensile Stress	2.73	2.66
Clevis Tensile Stress	1.20	1.17
Clevis Bearing Stress	1.83	1.79
Clevis Shear Tearout Stress	2.12	2.07

+ Safety Factor = (yield strength) ÷ (stress at noted load)

\* W<sub>s</sub> = Cask plus interviewing component load

Table 1 (cont'd)

## LIFTSCREW STRESS ANALYSIS - ITEM #1309, Figure 1

	Safety Factors	
	<u>3.0 <math>W_s</math></u>	<u>3.075 <math>W_s</math></u>
Thread Relief Diameter Tensile Stress	1.06	1.03
Thread Shear Stress	3.96	3.86
Hub Shear Stress	3.88	3.79
Hub Bearing Stress	2.70	2.63

## SECONDARY CROSS MEMBER STRESS ANALYSIS - ITEM #1100, Figure 1

	Safety Factors	
	<u>3.0 <math>W_s</math></u>	<u>3.075 <math>W_s</math></u>
Support Block Shear Stress (Under Lift Screw Hub)	4.64	4.53
Support Block Shear Stress (At Overhanging Edges)	2.69	2.62
4.25" Pin Bearing Stress	7.56	7.38
4.25" Pin Shear Tearout Stress	5.08	4.96
X-member Bending Stress	1.54	1.50

## PRIMARY HOOK STRESS ANALYSIS - ITEM 1200, Figure 1

	Safety Factors	
	<u>3.0 <math>W_s</math></u>	<u>3.075 <math>W_s</math></u>
Hook Arm Bending & Tensile Stress	1.15	1.12
Trunnion-to-hook Bearing Stress	2.28	2.22
X-member Bending Stress	4.76	4.64
6" Pin Hole Bearing Stress	5.13	5.00
6" Pin Hole Shear Tearout Stress	11.4	11.12

## LOWER ARM STRESS ANALYSIS - ITEM 2100, Figure 1

	Safety Factors	
	<u>3.0 <math>W_s</math></u>	<u>3.075 <math>W_s</math></u>
Clevis End Tensile Stress	1.61	1.57
Clevis End Shear Tearout Stress	1.10	1.07
Arm to Clevis End Tensile Stress	2.17	2.12

Table 1 (cont'd)

	Safety Factors	
	<u>3.0 <math>W_s</math></u>	<u>3.075 <math>W_s</math></u>
Arm Tensile Stress	2.21	2.16
Arm to Stirrup Shear Stress	1.43	1.40
Stirrup Side Plate Bending & Tensile Stress	1.11	1.08
Stirrup Bottom Plate Bending Stress	1.60	1.56

## CRADLE STRESS ANALYSIS - ITEM 2200, Figure 1

	Safety Factors	
	<u>3.0 <math>W_s</math></u>	<u>3.075 <math>W_s</math></u>
Cradle Bending Stress	2.30	2.24
Cradle Shear Stress	1.33	1.30
Lift Lug Stresses	1.21	1.18
Bottom Plate Stresses	1.18	1.15

## CASK TRUNNION STRESS ANALYSIS - ITEM 14, Figure 1

	Safety Factors	
	<u>3.0 <math>W_s</math></u>	<u>5.125 <math>W_s</math></u> **
Trunnion Bending Stress	1.35	1.42
Trunnion Shear Stress	2.95	3.10

\*\* Based on ultimate strength



#### 4.0 COMPLIANCE WITH NUREG-0612

The IF-300 redundant yoke and cask trunnions have been examined and found to be in compliance with the guidelines of NUREG-0612 as follows:

- 4.1 The yoke has been analyzed with a design load of three times the quantity of the static plus dynamic loads. The results are summarized in Table 1. All components meet the criteria that no yielding occur under design loading.
- 4.2 The cask trunnions have been analyzed with a design basis load of five times the quantity of the static plus dynamic loads. The results are also summarized in Table 1. The cask trunnions meet the criteria that their ultimate strength not be exceeded under design basis loading.
- 4.3 Crane hoist speed is limited by NUREG-0554 to 5 fpm for heavy loads such as the IF-300 cask. The maximum 5 fpm hoist speed limit will be clearly indicated on the IF-300 yokes.
- 4.4 The yoke has been fabricated and tested to requirements meeting the intent of ANSI Std. N14.6-1978.
- 4.5 The yoke will receive annual inspections and maintenance per the requirements of ANSI Std. N14.6-1978.
- 4.6 Utilities who own redundant cranes will be advised to use the IF-300 yoke in the redundant mode at all times except when unloading or loading the cask from the rail car.