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MAGNET DATA FOR REDESIGNED ORR CONTROL ROD MECHANISMS - INFORMATION SEQUENCE AND QUANTITATIVE ANALYTICAL FORM FOR COMMUNICATION BETWEEN MAGNETIC AND MECHANICAL MAN POWER

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ABSTRACT

A brief analysis of the required information sequence for converging both magnetic and mechanical design parameters upon a specific redesign of the magnet-actuated ORR control rod release mechanism is presented. A quantitative analytical language for communication between magnetic and mechanical design disciplines is suggested to facilitate an enduring and unambiguous flow and record of design information and agreement.

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In spite of the substantial effort which has been made to date to establish and record[1-4] in orderly form the relationship between the mechanical and magnetic design considerations which govern the redesign of the ORR control rod release mechanism, there still seems to exist a misunderstanding not only of the problem iteself but also of the analytical tools which have been created to simplify its solution. It appears necessary to record at least a brief exposition of the pertinent parts of the magnet problem and their relationship to the over-all redesign of the ORR control rod mechanism. The force acting against the magnet when a control rod is "cocked", as rods are during reactor operation, may be described as the sum of four forces. Refer to Table I for nomenclature.

$$P = F + W + s + h$$

It is required that the control rod execute a scram within the prescribed time whether the cooling water is flowing or static.

TABLE I

Nomenclature

F	release spring downward force on push rod
H	hydraulic force acting downward on control rod
h	that part of force H which appears as a downward force in the push rod
M	magnet holding force at 100% reactor power
P	total downward force exerted by push rod against magnet armature
S	net submerged weight of control rod
s	that part of S which appears as a downward force in the push rod
W	weight of push rod assembly less bellows upward force

A high value for P represents a high force driving the release mechanism toward the scrammed position. When the reactor is operating and the hydraulic force, H, is acting, P is the sum of the four factors listed above. However, in any case in which the water is not flowing and the control rods are cocked, the force P is reduced to:

$$P = F + W + s$$

It is evident that if h is a major part of force P, this latter condition substantially reduces the "scram force" on the push rod which releases the ball latch. As the magnetic holding force decays following a scram signal, it will at some instant becomes less than P, and ball latch release will occur. It is this time behavior of the magnet following a scram signal which is understood to cause concern. If it were possible to make h a smaller fraction of P, the sensitivity of control rod release time to water flow would be reduced. Since both W and s are largely determined independent of this release problem, the remaining way to reduce the fraction of P represented by h is to increase F. This represents a reasonable approach to the problem from the mechanical point of view but represents a direct increase in P, the load on the magnet, as F is increased. Thus the design compromise is defined. We may define:

$$F + W + s = A$$

and

$$P = A + h$$

A value of F must be selected to satisfy two conditions; A/P must equal or exceed some minimum value such that release occurs rapidly enough even when $h = 0$, and P must be low enough to represent a reasonable magnet design requirement. The former requirement tends to increase F and the latter to decrease it. The mechanical design is not greatly affected by this value of F, but the magnet design is very directly affected.

The design calculations made in reference 1 were published to demonstrate how this system could be optimized. If the equation for P is rearranged by grouping F with W and s with h, it is in a form in which the design information in reference 1 can be readily used.

$$P = F + W + s + h$$

Let

$$F + W = B$$

$$s + h = C$$

Then

$$P = B + C$$

The force B is independent of both the condition of water flow and of the design of the ball latch. Force C is a function of both of these. By making the incorrect but conservative assumption that when h is zero, s is also zero, the significant relationships may be clearly set forth. The error in magnet load so introduced is 15 lb or less for any case of interest.

1) water flowing $P = B + C$
2) no water flow $P = B$

To minimize this variation in P, it would be desirable for B/P to approach one. It should actually be sufficient for this ratio to have a value not less than perhaps 0.3, and this could be the form in which the Instrument and Controls people elect to supply the required information. The above ratio is assumed as a value reasonable for purposes of discussion. The analyses in reference 1 demonstrate how C can be varied within limits not only to meet the mechanical design requirements but also to ease the task of designing a magnet which would maintain B/P at or above the required minimum value. The following example will serve to demonstrate how the redesign may be completed when the magnet data are received and also how the magnet designer can make use of reference 1 to avoid magnet requirements beyond present technology.

Consider four cases: two for a 15-deg plunger angle, α, and two for a 30-deg plunger angle. For each of these, consider shim rod shoulder angles, γ, of 45 deg and 55 deg. Refere to Fig. 6 of reference 1 and multiply the normal ball-to-surface forces indicated by eight to account for the eight-ball arrangement in the ORR system. These forces are in turn multiplied by the sine of the angle α to yield the force C. See Table II.

For present conditions in the ORR, force B is about 75 lb. This figure is quoted approximately because the spring forces are known to vary somewhat.

TABLE II

Case	Force C, lb
1) $\alpha = 15°$, $\gamma = 45°$	94.2
2) $\alpha = 15°$, $\gamma = 55°$	72.7
3) $\alpha = 30°$, $\gamma = 45°$	187
4) $\alpha = 30°$, $\gamma = 55°$	144

Now assume the magnet designer wishes to hold the ratio B/P to a minimum value of 0.3 Determine the values which F must take for each of the four cases listed. To allow for some increase in the push rod weight above that of the present ORR push rod, W is taken as 15 lb. This increase is required to overcome some of the problems presently contributing to false scrams.

$$B = F + 15$$

Table III tabulates the values of F appropriate to the four cases of the example.

TABLE III

Maximum Release Spring Force Permissible for Examples in Table II when B/P Is Defined as 0.3

Case (Table II)	Release Spring Force F, lb	Magnet Force at 100% Power, safety factor = 2
1	25.4	270
2	16.2	208
3	65.2	535
4	46.8	412

These F values are solutions of the relationship between F and C.

$$\frac{B}{P} = \frac{F + 15}{B + C} = 0.3$$

$$F = 0.3\,(F + C + 15) - 15$$

$$F = 0.429\,C - 15$$

It is helpful in visualizing the meaning of these results to keep in mind that:

$$\frac{B}{P} + \frac{C}{P} = \frac{B}{B + C} + \frac{C}{B + C} = 1$$

If a safety factor is introduced in the form of the requirement that $M = 2\,P$ at 100% reactor power, the holding force of the magnet at full reactor power must, for the examples listed, be as shown in the right column of Table III.

$$M = 2[B + C] = 2[F + C + 15]$$

It is hoped that this memorandum will be found helpful by the Instrument and Controls personnel either in affording a specific quantitative means for determining, communicating, and recording design information or in developing an even more specific and useful form of statement which more closely fills their needs.

References

1) J. Foster, Calculation of Three-Vector Force System on ORR Control Rod Ball Latch Mechanism with Parametric Boundary Condition Solutions for Optimization of Ball Latch Redesign, ORNL CF-61-12-77, December 29, 1961.

2) J. Foster, Relationship between Plunger Travel and Shim Rod Region for Two ORR Control Rod Ball Latch Configurations, ORNL CF-62-2-9, February 7, 1962.

3) J. Foster and G. L. Rhoden, ORR Control Rod Drives — Failure to Scram, Intra-Laboratory Correspondence, January 31, 1961.

4) J. Foster and G. L. Rhoden, ORR Control Rod Drives, Intra-Laboratory Correspondence, February 6, 1961.

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