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CONSEQUENCES OF THE IMPROVEMENT OF FAST REACTOR MATERIAL BEHAVIOUR UNDER IRRADIATION ON FUEL ELEMENT PERFORMANCE

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INTRODUCTION

Summarising the work done on fast reactor fuel element during the last years, it could be said that the most important problems come from the excessive swelling of the structural materials used (1). Hence the limitations of irradiation time for a given reactor result from the cladding or hexagonal wrapper deformations. It was also recognized that irradiation creep plays a major role, either in inducing additional deformations, or in providing possible ways of accommodation of bending stresses.

Even if the mechanisms of these phenomena are not today fully understood, progress has been made in designing swelling resistant and/or low irradiation creep modulus materials. For instance in FRANCE, annealed 316 SS has been eliminated from pin and subassembly, and replaced by cold worked 316 ; we are now considering introduction of stabilizing elements in 316 SS as a further improvement and studying different alloys (nikel alloys, or ferritic steels) which could become reference candidate in some years (fig. 1). Of course, it has to be checked that the improvement of irradiation characteristic

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is not counterbalanced by losses on other properties (embrittlement for instance).

Considering that pushing off or eliminating a limit may lead to the onset of a new one, we propose in this paper to make a review of the consequences of substantial improvement of structural material behaviour.

OXIDE BEHAVIOUR

The reduction of clad diameter variations induced by irradiation could enhance problems of oxide swelling accommodation and interaction with clad. Nevertheless, we have up to now experimentally observed that the space provided in the gap and in the porosity is sufficient to reach high burnup with the lowest swelling cladding (even in RAPSODIE where burnup/fluence ratio is higher than in a large power reactor) ; no evidence of mechanical interaction has been found. So we stay aware of this problem but without being afraid of any severe limitation in performance at least under permanent operating conditions (3). Fig. 2 illustrates this problem : our effort is aimed at obtaining materials leading to reduced $\Delta D/D$ at high burnup ; probability of mechanical interaction appears at burnup increasing with $\Delta D/D$; we do not know if there is a region critical from this point of view.

PIN BEHAVIOUR

As differential swelling due to temperature dependance induces stresses in cladding, a reduction of absolute value is favorable ; we think that irradiation creep deformations occur without damage. Low swelling materials would also be beneficial from the point of view of mechanical interaction between spacing wire and cladding.

BUNDLE BEHAVIOUR

It is obvious that space available for sodium flow will be less restricted if the deformation of all components is minimized.

We have experimental evidence that the ability of the helicoidal wire spacing system to accommodate substantial pin distorsions is high (4); nevertheless, limits are to be put on these distorsions to control mechanical interactions, apparition of local hot spots (rather than generalized flow restriction) and these limits will be lower the lower the hexagonal wrapper deformation Fig. 3. shows that reduction of clad and duct deformations has consequences on interaction possibility and can lead to different nature of in pile life limitation.

HEXAGONAL WRAPPER BEHAVIOUR

If we consider it only as a component of the subassembly (i.e. excluding the problems of whole core behaviour), we find evident that variations of distance across flat and of length have to be limited, but also bowing for correct handling possibility. So, swelling reduction is again favorable, but we can notice that, ideally, irradiation creep should be low enough to limit across flat distance increase, but not too low to prevent it from restraining bowing stresses.

CONCLUSION

Swelling reduction appears everywhere to be beneficial, but particular attention is to be given to the consequences of oxide swelling accomodation. On the contrary, it might be useful that, as long as swelling is not quite zero, some irradiation creep remain present to accomodate the resulting deformations and stresses.

These considerations are general and remain qualitative. The task of engineers dealing with project studies is to take into account the present state of knowledge to make the best choice of characteristics (nature of materials, detailed dimensions) in order to meet the objectives.

Large increases in burnup from the initial objectives, have already been attained; the 100 000 MWd/t target will be reached in a very near future and the studies under progress will bring further improvements beyond that value.

(1) J. LECLERE et al.
Problems encountered in the design of fuel elements for fast breeder reactors. Solutions taken up in FRANCE.

MONTEREY - March 1979

(2) J.M. DUPOUY et al.
Swelling and irradiation creep of 316 stainless steel.

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(3) J. ROUSSEAU et al.
Fast Neutron Reactor Fuel Elements : Power Grid - Duty Problems.

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(4) P. BLANCHARD et al.
Observations on the geometry of an irradiated Rapsodie subassembly.

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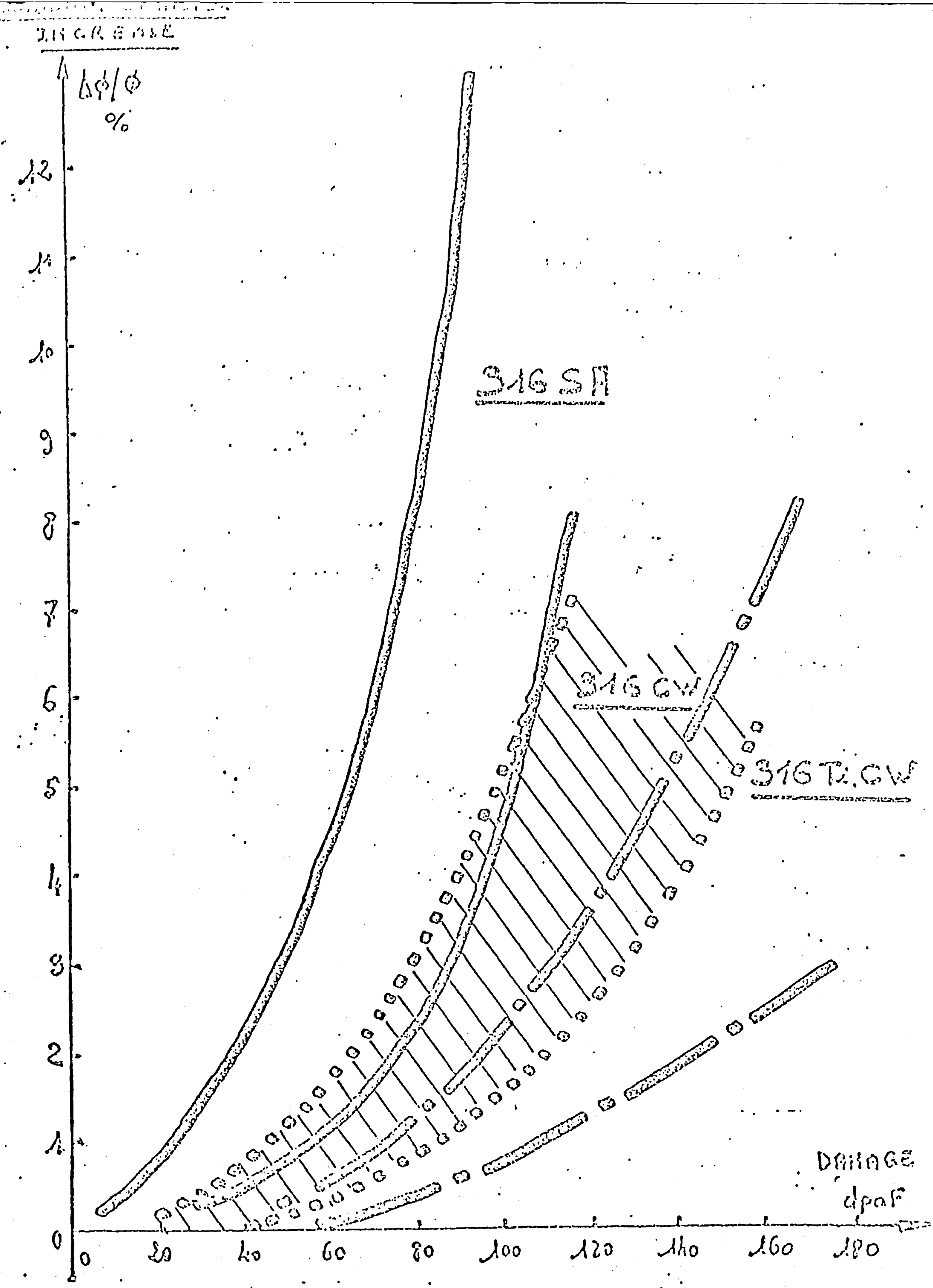

Fig 1 - IMPROVEMENT IN CLADDING IRRADIATION INDUCED DEFORMATIONS

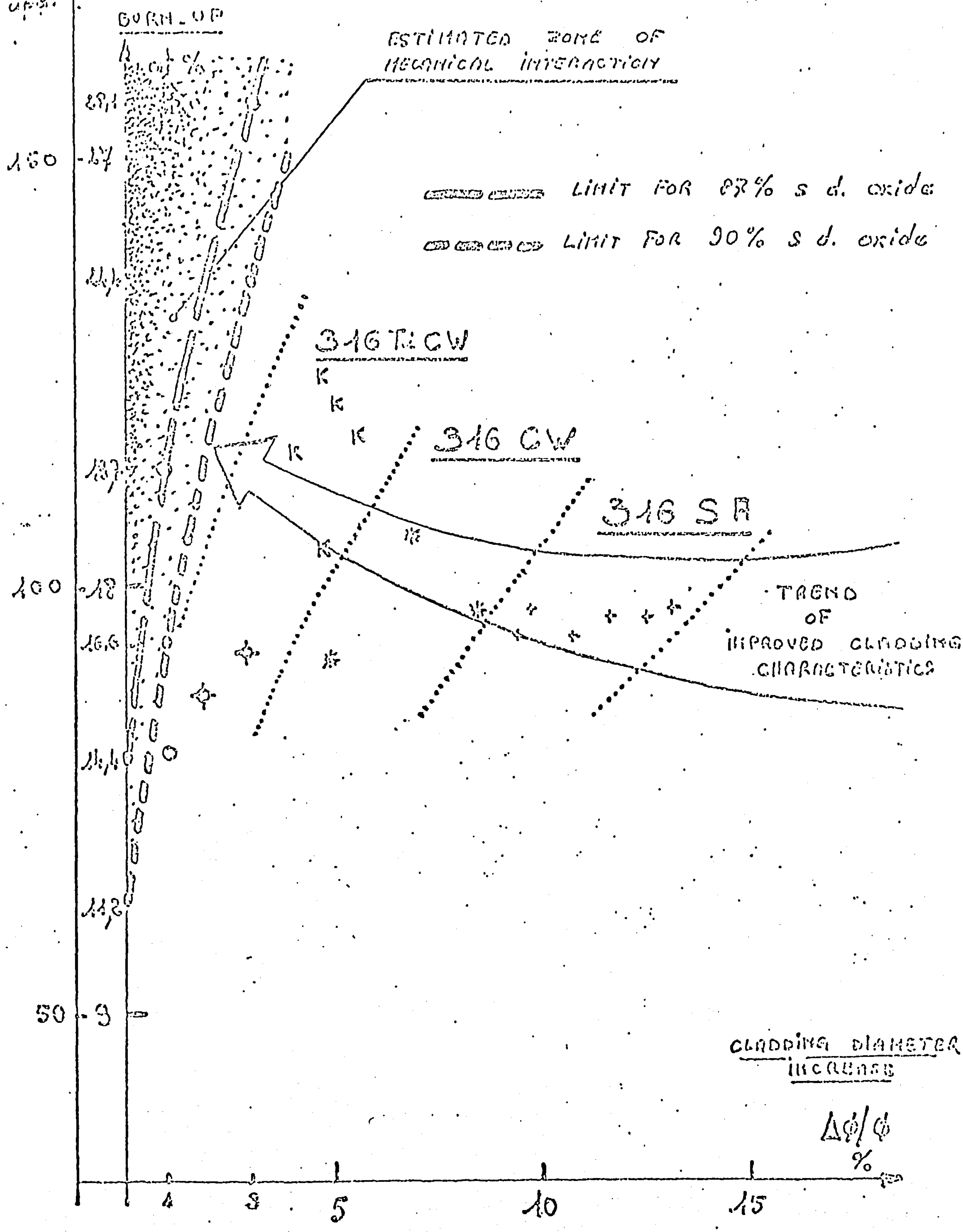

Fig 2. PROBLEM OF MECHANICAL INTERACTION BETWEEN OXIDE AND CLADDING

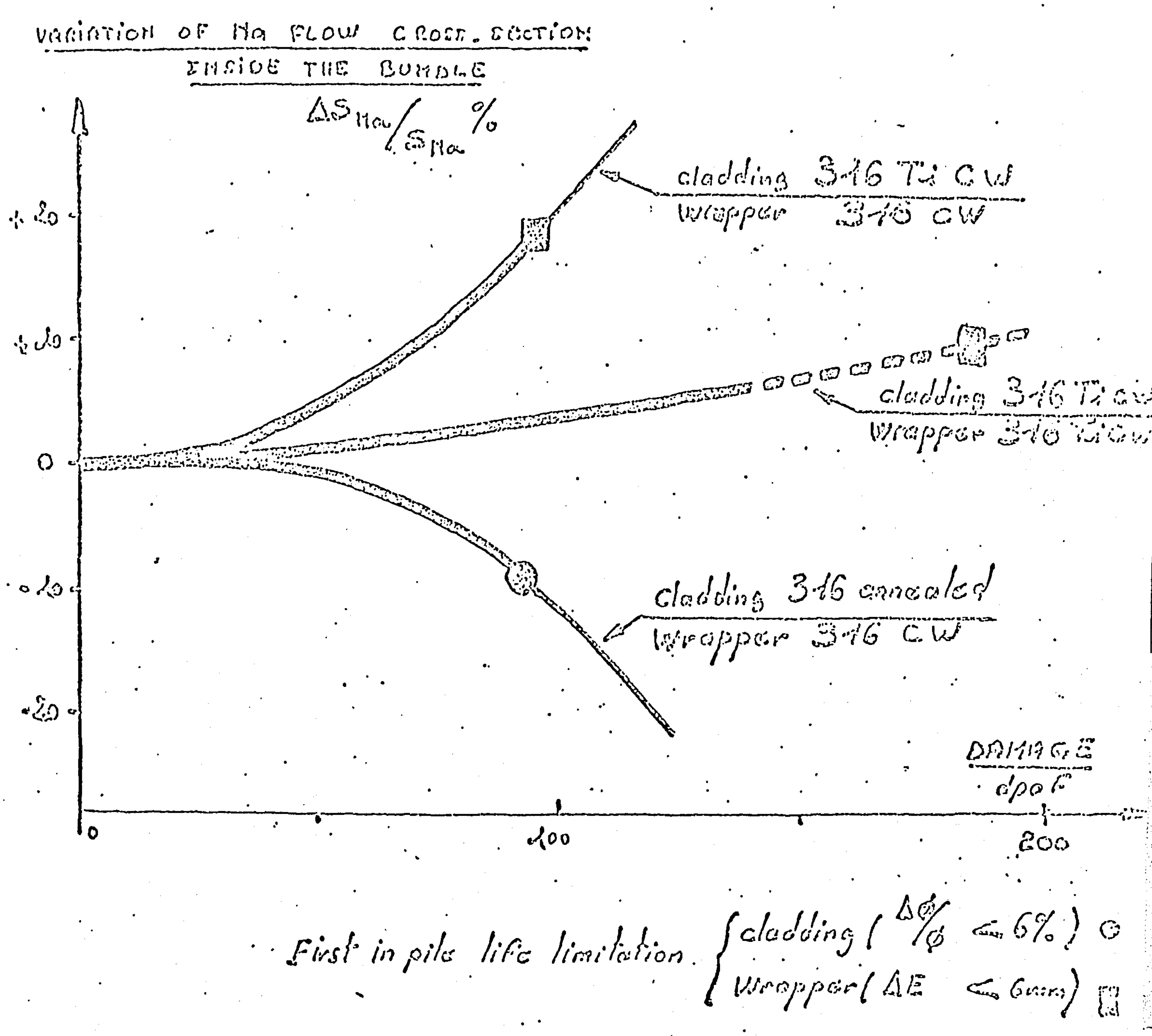

Fig 3 . CONSEQUENCES OF PINS AND WRAPPER DEFORMATIONS