# FUTURE STEAM GENERATOR DESIGNS
## (Single Wall Designs)

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The easily removable 'U' tube design style adopted in the UK for the existing PFR Steam Generators, the Replacement Units now in production and for the future CDFR, gives the operator an extremely valuable option in the event of a water/steam leak occurring inside the Steam Generator.

He can choose to shut-down, attempt to find the leak, assess damage, repair, revalidate and return to service in situ, or he can elect to remove the defect unit and replace with a "proven" spare before returning the circuit to power.

With the latter approach the resultant outage time is a known entity of about two weeks. If a repair is attempted in situ, predictions of outage time can become a matter of guesswork since one has no "guaranteed" method of leak location and the assessment of secondary damage may be very time consuming, depending on the size and type of the original leak together with the particular design style of the Steam Generator.

A further significant advantage of the removable 'U' tube design concept is that periodic interchanging of bundles with a spare enables routine chemical cleaning and thorough scheduled tube inspections, with specimen tube sample removal if required for monitoring purposes. If necessary, bundle decontamination can be undertaken to assess engineering deterioration to various degrees of thoroughness ranging from 100% equivalent factory final assembly inspection, to partial decontamination operating via a glovebox type of maintenance bag arrangement, examining local points of both shell and tube areas of the bundle.

Many lessons from the last five years' experience of PFR will be incorporated into the design of the CDFR and PFR Steam Generators have two very good examples of how the designer can ease or severely handicap the operator in coping with sodium/water leakages.



Good, quick access to tube ends is achieved in the existing PFR Evaporator by simply unbolting the steam/water closure head, but on the superheater and reheater hand-caps have to be cut off and only extremely limited and difficult access to the tube plate can be obtained (see Figures 1 and 2).

Thus, for the replacement PFR superheater and reheater now in production, design changes have been introduced which improve the facilities for inspection, improve the engineering integrity of the sodium/water boundary and will enable NPC to prove the new units under real power station operating conditions. The CDFR design (Figure 3) is a scaled up replica of the Replacement Units and we, therefore, hope to validate the CDFR design by the successful operation in PFR of the new prototype units some time during 1981.

Before describing these changes in more detail, it is worthwhile to comment upon the potential advantages of the gas space requirement in the PFR type of removable 'U' tube. With regard to sodium\water reaction events in the high risk area of the PFR Steam Generators has proved to be in the tube to tube sheet welds and it is fortuitous that the provision of a sodium side gas space enables the designer to incorporate a highly sensitive leak detection system, with a large "window of protection" value for the monitoring of the critical weld feature.

Thus, if the operator wishes, he can lower the level of the sodium during leak location operations and convert what would be a more onerous under-sodium leak into a gas space leak. If any opening up operations are required, then this could be of some advantage.

DESIGN CHANGES FROM PFR TO CDFR AS INCORPORATED INTO THE PROTOTYPE REPLACEMENT STEAM GENERATORS

a) Tube\tubeplate welds have been eliminated - the sodium boundary at the brazed thermal sleeve joint is now only a low pressure gas seal.

b) Tunes are brought out as individual items and welded into local pods or headers with a flanged end cap bolted on so as to obtain speedy access when required -local cooling of the pod means that the bundle proper cn be kept hot if required.

c) Access to the underside of the sodium seal plate (albeit limited) can be obtained through various penetrations provided for instruments and it has been demonstrated on PFR that the bundle can be raised in its shell whilst being contained within a local glovebox\bag device. This enables the outer sodium outlet side of the bundle to be inspected on the sodium side.

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d) To gain direct viewing access to the tube bore, tail pipe bends at the top of the unit can be cut out and re-welded (using specially developed orbital welding machines with wire feed). Periodic inspection using ultrasonic techniques will be carried out to monitor any wall thinning effects, particularly at grid support points where fretting damage may occur. Similarly, eddy current probe examination of the bore side will be done.

e) Consideration is being give to having some experimental tubes in the outermost rows of the bundle which will be removed during subsequent operation for materials monitoring purposes. The tubes would be cut out and possibly replaced by dummy tubes.

f) There is scope in the design for sacrificing a few tubes in the bundle to allow the space to be occupied by an instrument guide tube which could penetrate down inside the bundle proper. This would enable any future possible development of leak detection probes to be lowered into the bundle at various levels should this be required.

INSPECTION (normal scheduled maintenance)

It is envisaged that routine maintenance will be carried out in situ during major plant shutdowns (turbine) every two years or so as follows:

- Selected tubes and some chosen at random will be visually inspected on the bore side checking for pitting and the condition of the magnetite layer, with respect to the need for chemical clean. The cut out tail pipe bend is available for metallurgical examination if required.

- In addition, tubes will be "fingerprinted" using ultrasonic and eddy current techniques to assess the severity of wall thinning at critical tube\grid support areas and the surface defects at the bore. Comparison with records of as-built readings should enable engineering deterioration to be assessed.

- Occasionally, depending upon the operating history - if the "spare" unit has been installed then the opportunity will arise to inspect the shell side and confirm ultrasonic data on wall thinning via glovebox/bagging techniques or on a completely decontaminated bundle. Tube specimen removal would be possible at this time if required, and local decontamination at critical grid\tube fretting points will enable close inspection of these areas to be achieved.

- Apart from visual inspection of the upper gas plenum via instrument holes, no scheduled inspection is planned for on the sodium side. 

In the case of a leak situation arising, since we consider these will be very few in the design of unit, it is recommended to replace with a spare whilst the defect unit is being repaired and revalidated as being fit for service - this gives the maintenance engineer considerably more scope for carrying out a more thorough job of the location and repair of leaks after leaks, and a simple test vessel facility can be provided to give maximum capability. However, the problem can be solved in situ if required.

The new PFR units have considerable flexibility to adopt more and more searching leak location techniques as these become available, but it is considered that the "mole" technique mentioned earlier in the paper will suffice. The preparations and sequence of events, assuming a "confirmed" leak has been established, will be to:

1. Take the offending circuit off load (in CDFR station output could probably be maintained close to normal due to the increased number of circuits and allowing the other units to run on stretch capacity for a known small period of time), isolate the steam side and pad the unit with high pressure steam or argon. Examine the operational records, ascertain size and position of the leak (above or below the Na level) and reduce the plant conditions to safe level. This may involve washing the underside of the sodium seal plate and/or lowering sodium levels.

2. Decide on an in situ repair or a "spares" interchange policy - assume the former applies.

3. Reduce the plant conditions to the state when mechanical work can be done, i.e. local cooling of the pod end caps, reduce pressure inside the unit, remove end caps and "mole" through the tubes to locate the suspect tube area, carried out from the modular pod headers.

4. Careful rechecking of the offending area is then envisaged to establish exactly the number of leaks. Depending upon the pattern of these (hopefully only one) decisions will be taken to cut out the bends of the defect tube and the six surrounding ones - further cooling down of the unit top end will be required, but the tube itself can still contain sodium at a reduced temperature.

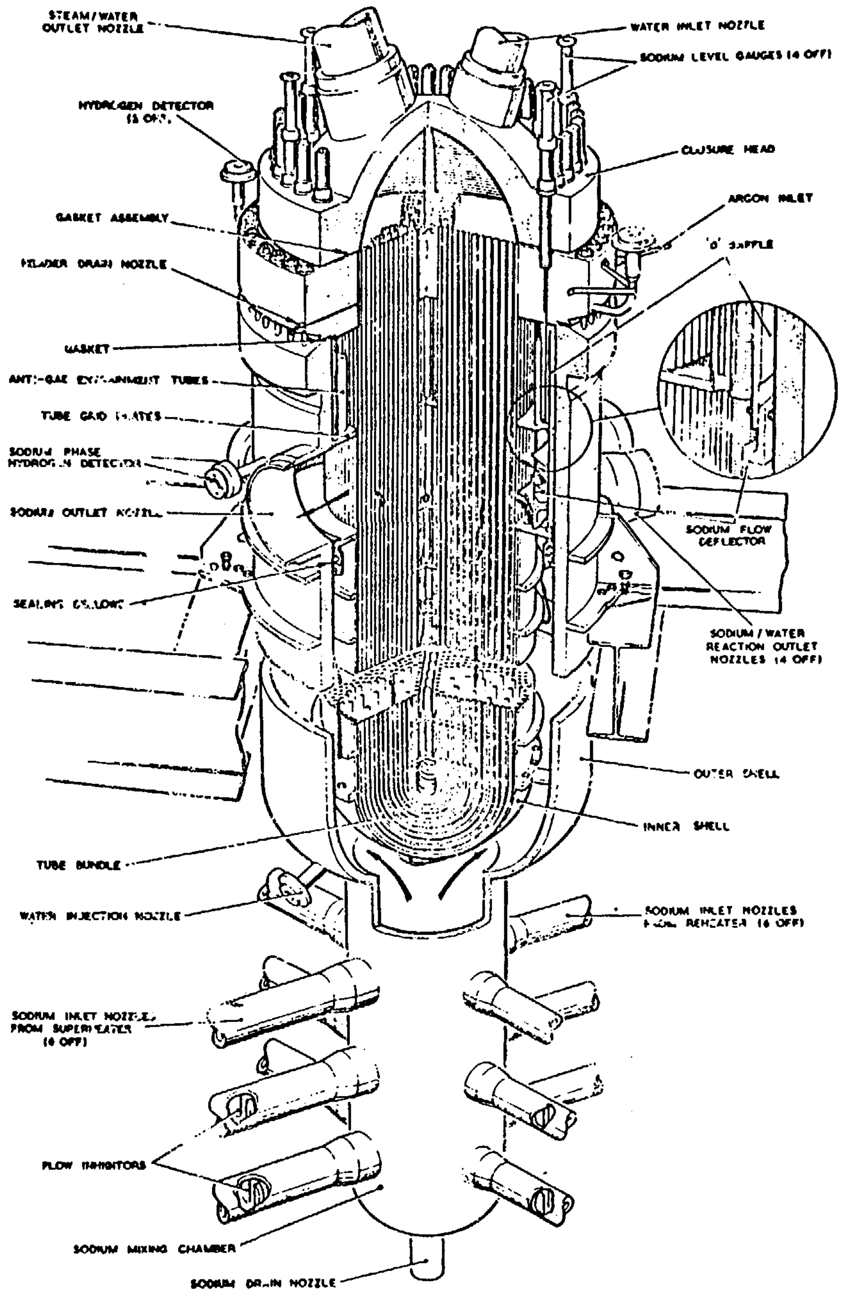
5. Careful visual/eddy current and ultrasonic examination will then be carried out on these tubes to assess secondary wastage damage.

6. Assuming this is acceptable, the defect tube will be capped off. The criteria for acceptance of adjacent wall thinning (if it has occurred) is yet to be established, but depending upon its position in the bundle, local thinning of at least 20% to 30% should be acceptable.

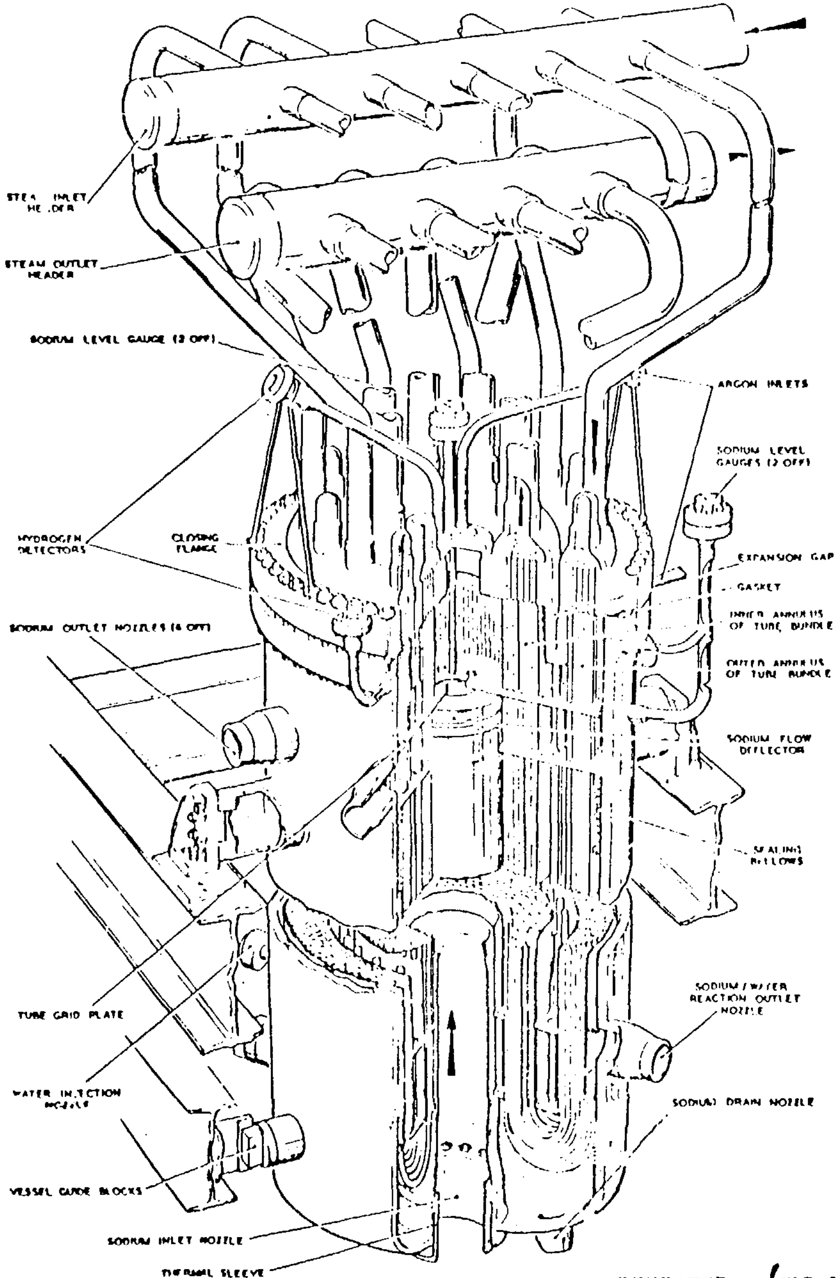
7. The repaired area could then be proof-tested locally via its pod isolation arrangement, welds crack-detected and radiographed before replacing the hand caps on the pod headers, complete with its local small fitted insulation package and heating up to the top end of the unit to bring it back into generation.

Should the above prove to be unsatisfactory, then more and more sophisticated gas pressurisation techniques and steam opening up operations could be put into action. This is when the alternative of replacing with a spare begins to look really attractive. Since in situ and external repair methods both involve circuit cooling and warm-up times the downtime penalty for the simple "mole" procedure is comparable to the known time of the "spares replacement philosophy", thus the option to repair in situ will probably be tried first - unless it is evident from the outset that the leak has been serious enough to justify going for the swap policy.

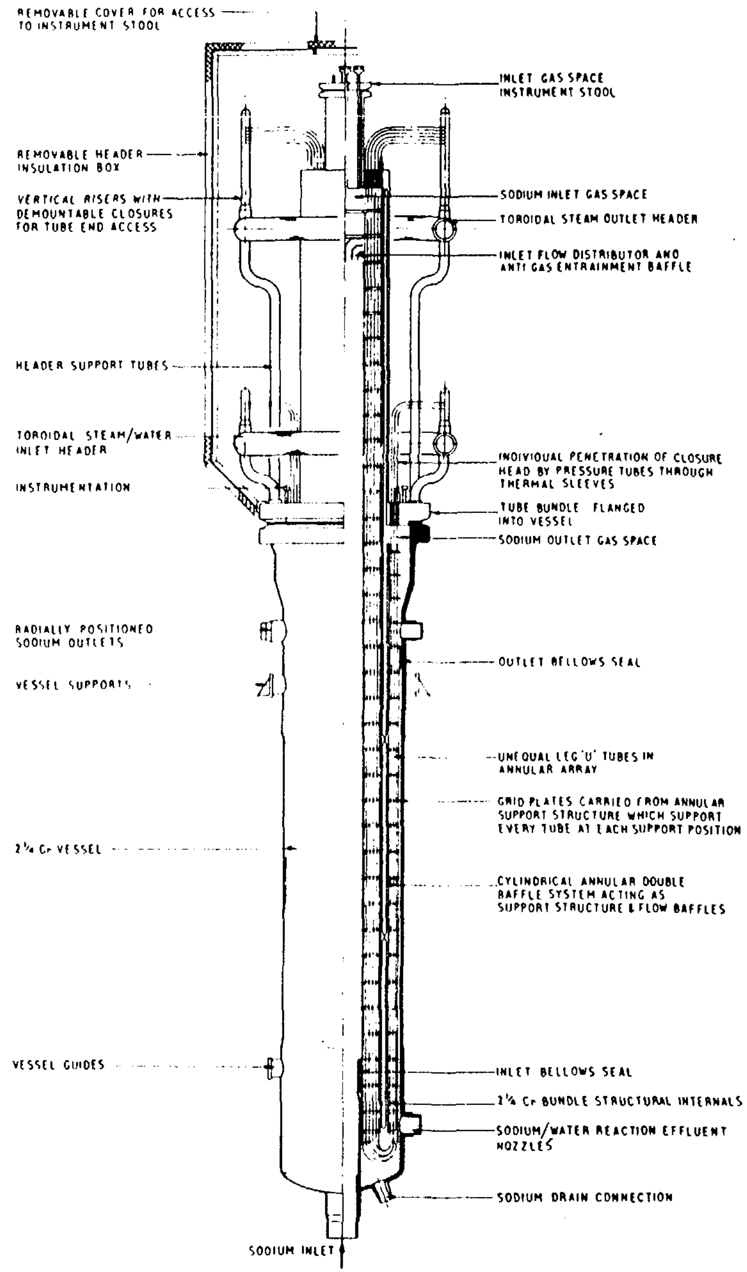
As the repaired unit is being put on load, it is envisaged that very careful monitoring of the hydrogen detection system is being carried out to get early warning of any suspicious signals.




EVAPORATOR FIG 1




REHEATER (FIG 2)




PRINCIPLE FEATURES OF CFR STEAM GENERATOR

(FIG 3)