High Quality Tube to Tubesheet Joints - When, Where and Why,

A. F. Lillie, Energy Systems Group

High quality tube-to-tubesheet joints are required wherever and whenever a failure of the joint can lead to an extended plant shutdown (and consequent economic loss) due either to damage to the heat exchanger or lengthy time to locate and repair the leak and requalify the unit for service. A prime example of such a joint occurs in the steam generator tube-to-tubesheet joints of a sodium-cooled fast breeder reactor where the welds separate highly reactive fluids (sodium-and-steam/water).

The Atomics International (AI) division of Rockwell International's Energy System Group is currently designing and building the steam generators (evaporators and superheaters) for the nation's first large breeder reactor, the Clinch River Breeder Reactor (CRBR) plant near Oak Ridge, Tennessee. The integrity of the tube-tubesheet joints (1514 welds per unit in a total of 9 units) over the 30 year lifetime of these units is crucial to the demonstration of the fast breeder reactor as a reliable, economic energy option for production of electricity in the years ahead.

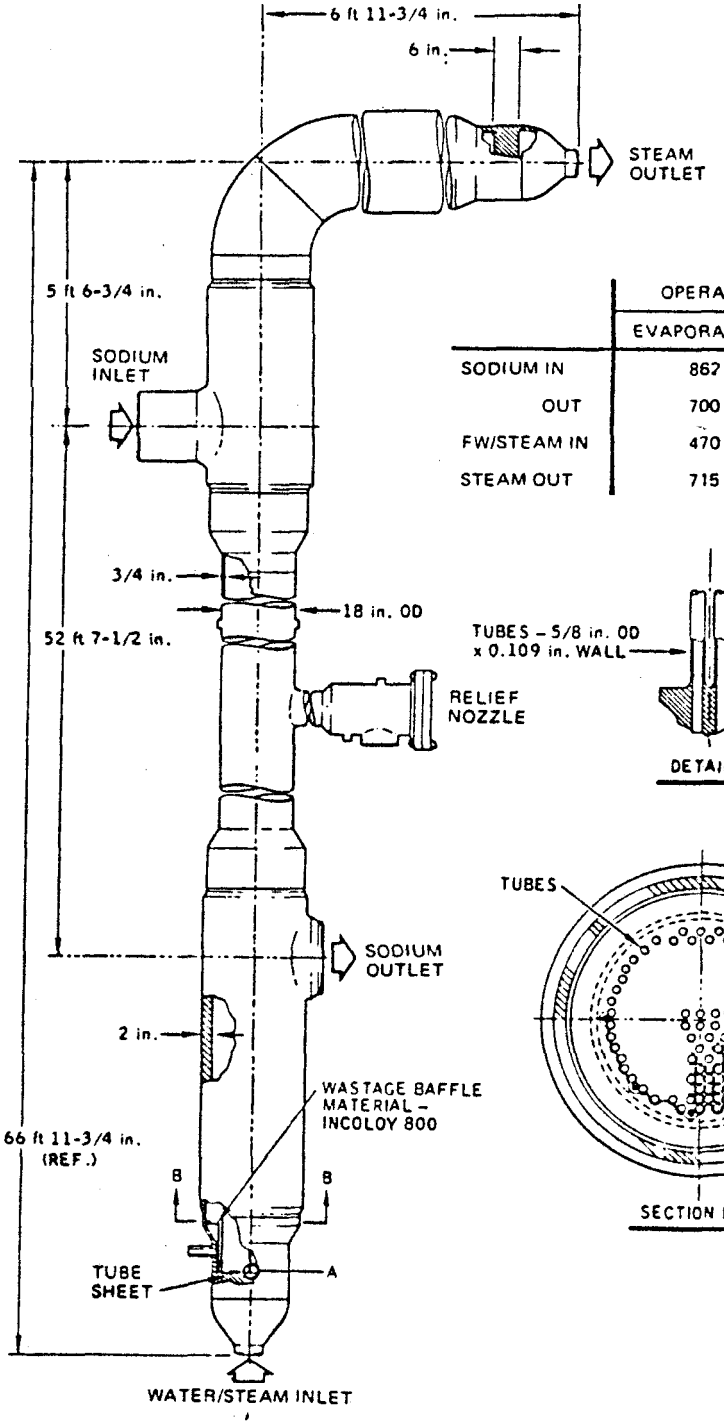
The joint is an autogenous butt weld performed using the internal bore weld (IBW) process. The weld is fully inspectable using high precision radiography and ultrasonic techniques in addition to standard visual, liquid penetrant and helium leak check inspections. The tubes and tubesheets are fabricated from high purity 2¼ cr-1Mo low alloy ferritic steel, and, as a precaution against in-service weld cracking, each tube-to-tubesheet weld is heat treated prior to inspection.

The weld was originally developed under a Rockwell funded program which designed and built a 30 MWT test model of the AI "hockeystick" steam generator, known as the AI Modular Steam Generator (AI-MSG). As a result of the flawless performance of that unit in the early 70's, the hockey stick was selected by DOE as the reference steam generator for the CRBR. AI was awarded the current contract for design and fabrication of the CRBR steam generators in late 1975 and is currently in the process of building the 11 units (1 prototype, 9 plant units plus 1 spare plant unit).

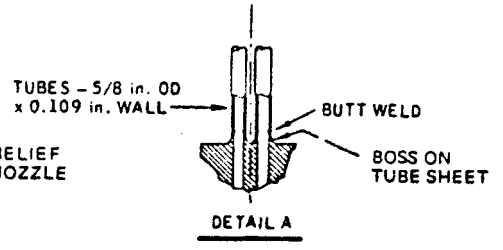
An integral part of the contract was the requirement for further development and refinement of the tube-to-tubesheet weld, leading to definition of acceptance criteria for the weld based upon the highest quality weld reasonably achievable in the development phase of the program. The acceptance criteria are based on the use of a high precision microfocus rod anode radiography technique capable of imagining 1 mil porosity levels. In addition, a special ultrasonic inspection technique was developed by AI to measure the weld geometry (concavity, convexity, wall thinning) to assure that the welds meet the necessary configuration requirements. Special post weld heat treat equipment and techniques have been developed to allow individual PWHT of each and every weld prior to inspection.

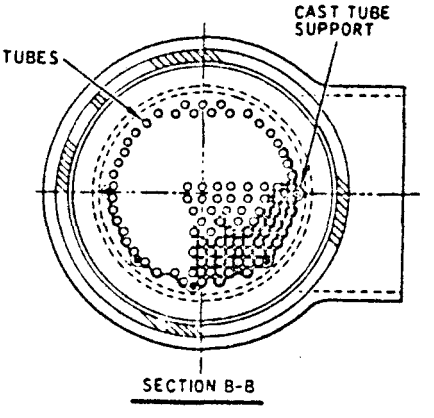
In summary, the tube-to-tubesheet welds in the CRBR steam generators are among if not the highest quality welds being produced in industry today. These stringent quality requirements must be met if this most critical of fast breeder reactor components--the steam generators--are to function reliably and assure a place for the breeder reactor option in the future energy supply for the United States.

AI-MSG EVAPORATOR/SUPERHEATER MODULE



	OPERATING TEMPERATURES	
	EVAPORATOR	SUPERHEATER
SODIUM IN	867	950
OUT	700	862
FW/STEAM IN	470	715
STEAM OUT	715	905





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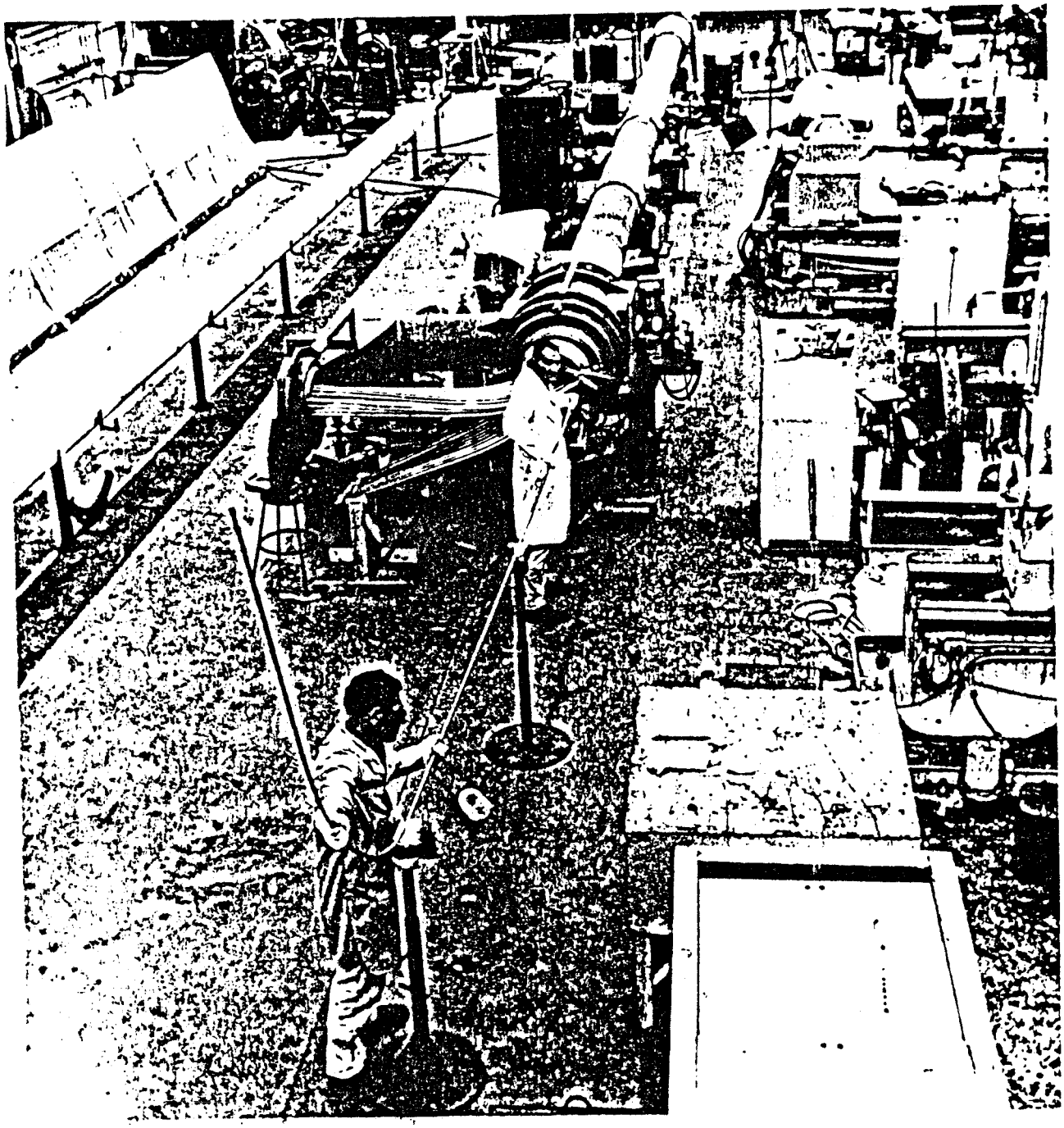
AI HOCKEYSTICK STEAM GENERATOR
—1970—
AI MODULAR STEAM GENERATOR (AI-MSG) FABRICATION



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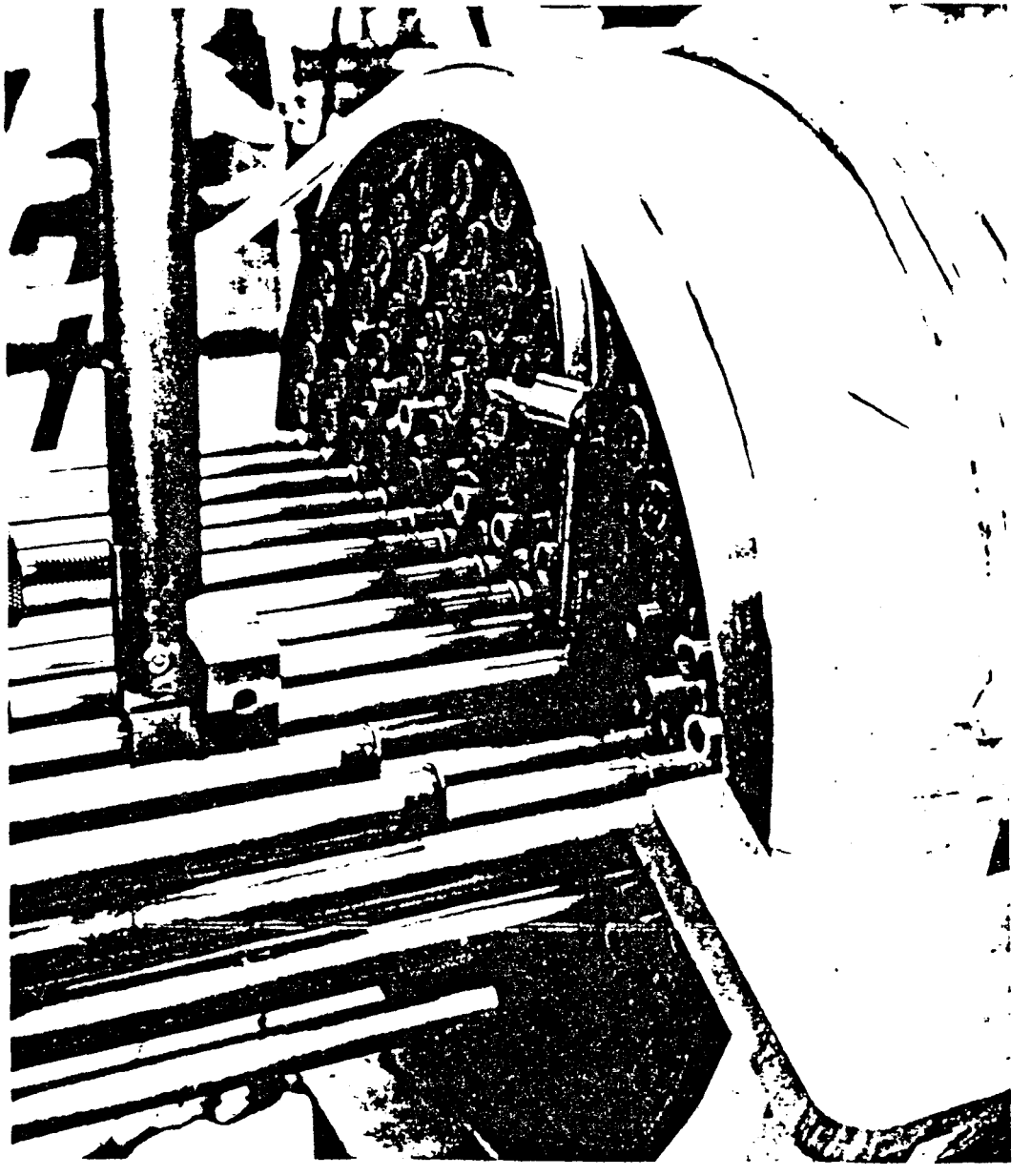
AI HOCKEYSTICK STEAM GENERATOR —1970—

HIGH RELIABILITY TUBE-TO-TUBESHEET WELD DEVELOPED



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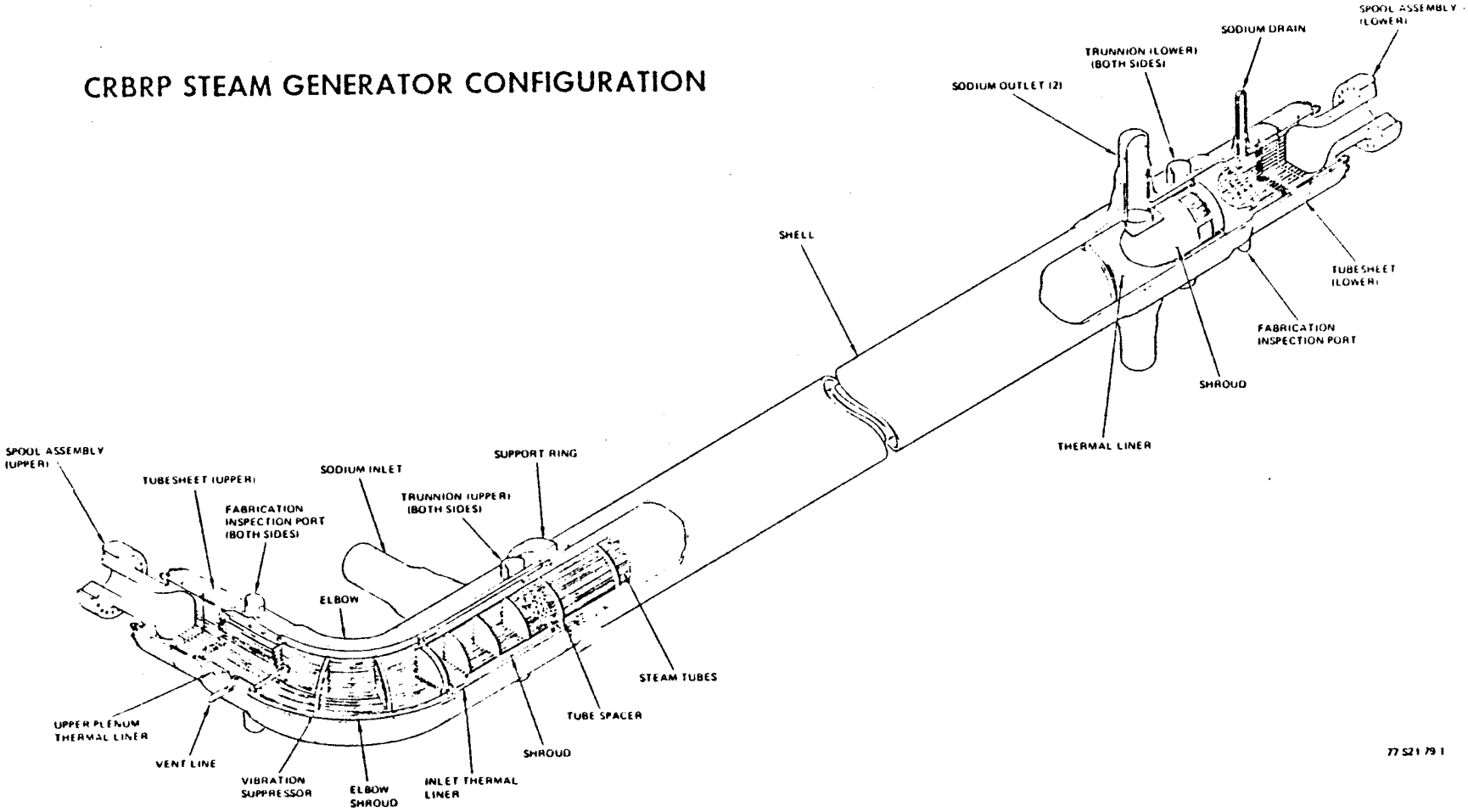
CRBRP STEAM GENERATOR CONFIGURATION



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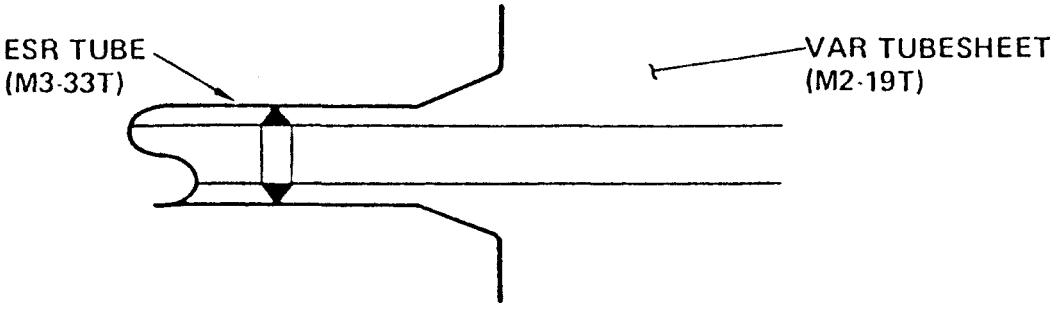
FULLY INSPECTABLE TUBE-TO-TUBESHEET JOINT HAS HIGH RELIABILITY

- FUNCTION

  TUBESIDE CIRCUIT SEAL FORMING A PORTION OF THE SODIUM – STEAM/WATER BOUNDARY

- CONFIGURATION

  AUTOGENOUS BUTT WELD OF 2-1/4 CR - 1 MO ESR TUBE – TO – 2-1/4 CR - 1 MO VAR MACHINED TUBESHEET SPIGOT (1514 WELDS PER STEAM GENERATOR)



- FUNCTIONAL REQUIREMENTS

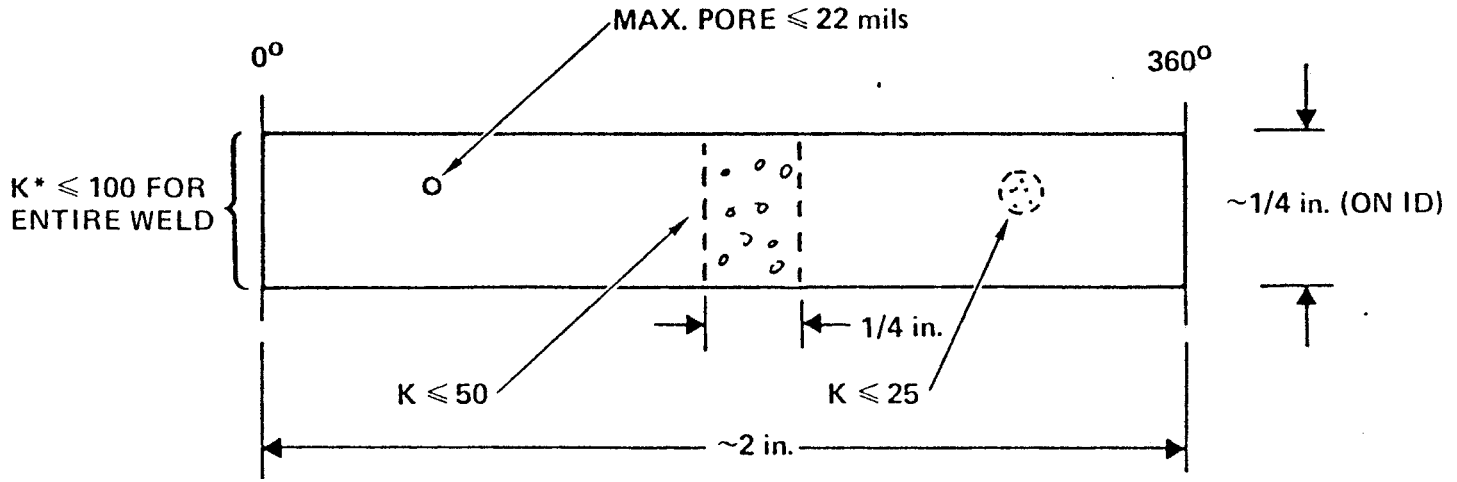
  HIGH RELIABILITY, FOR 30 YEAR DESIGN LIFETIME, AGAINST STEAM/WATER-TO-SODIUM LEAKS

- INSPECTIONS PERFORMED

  VISUAL
  HELIUM LEAK CHECK
  DYE PENETRANT
  RADIOGRAPHY (ROD ANODE)
  ULTRASONIC (FOR GEOMETRY)

POROSITY ACCEPTANCE CRITERIA IS VERY STRINGENT

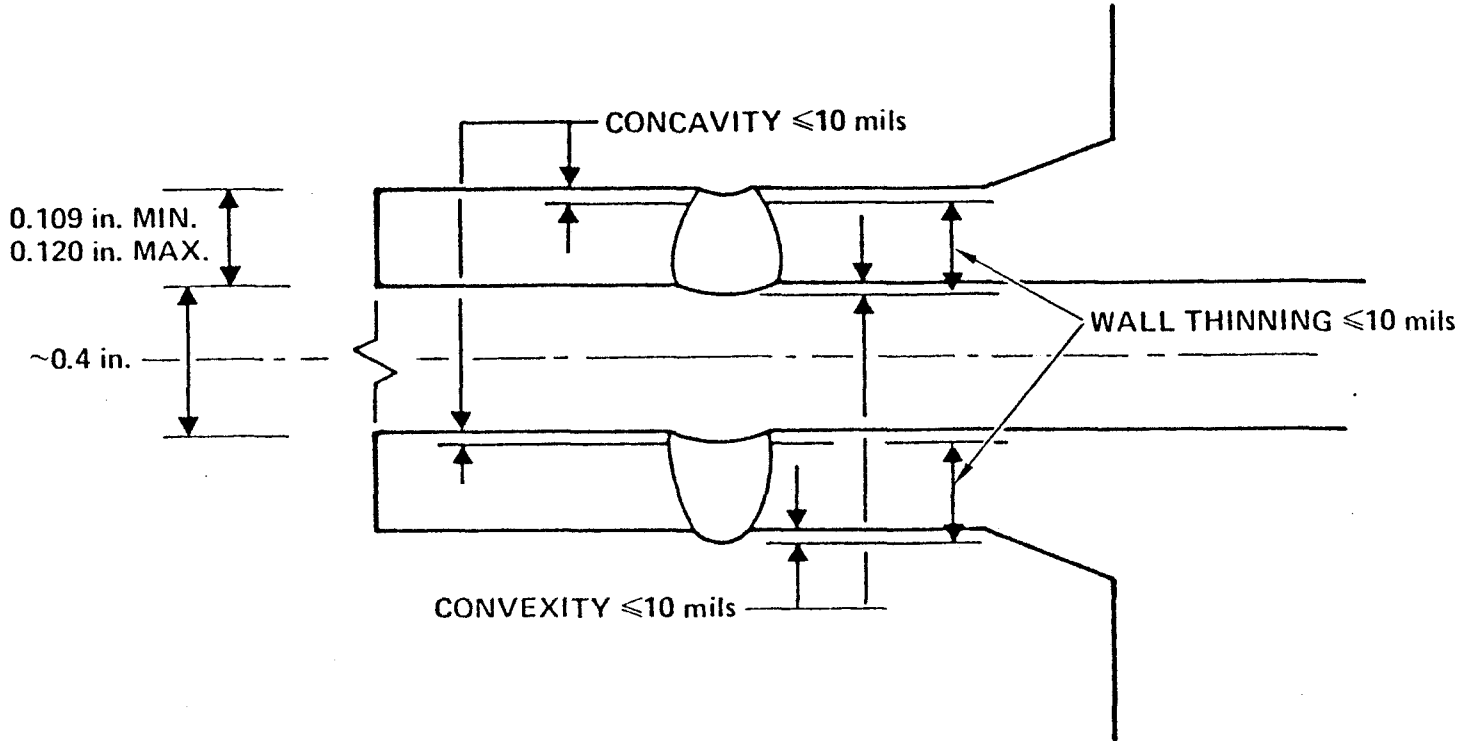
WELD RADIOGRAPH DEPICTED



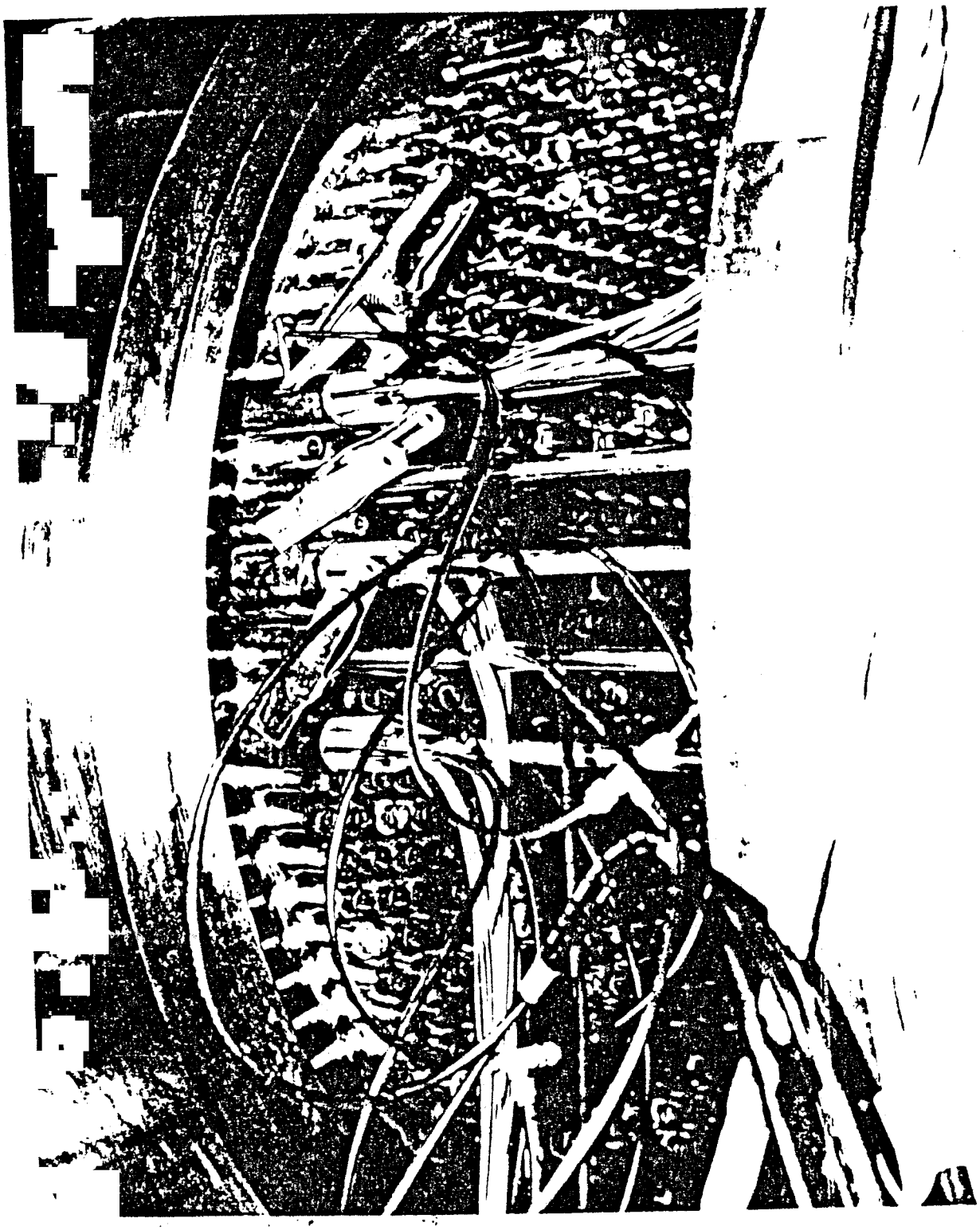
*K FACTOR = SUM OF DIAMETERS (in mils) OF ALL PORES EXCEEDING 5 mils IN DIAMETER

WELD MUST MEET TIGHT CONFIGURATION REQUIREMENTS

UNCONSTRAINED 5G WELDING IS USED



EACH WELD IS INDIVIDUALLY POST WELD HEAT TREATED



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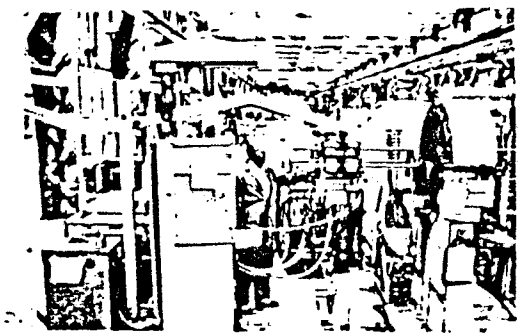
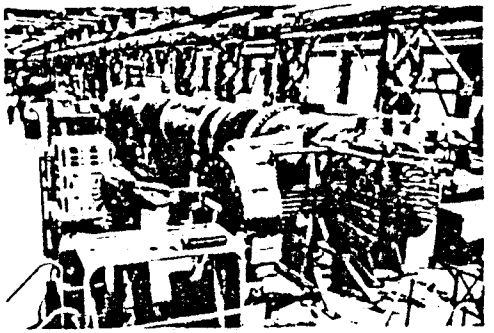
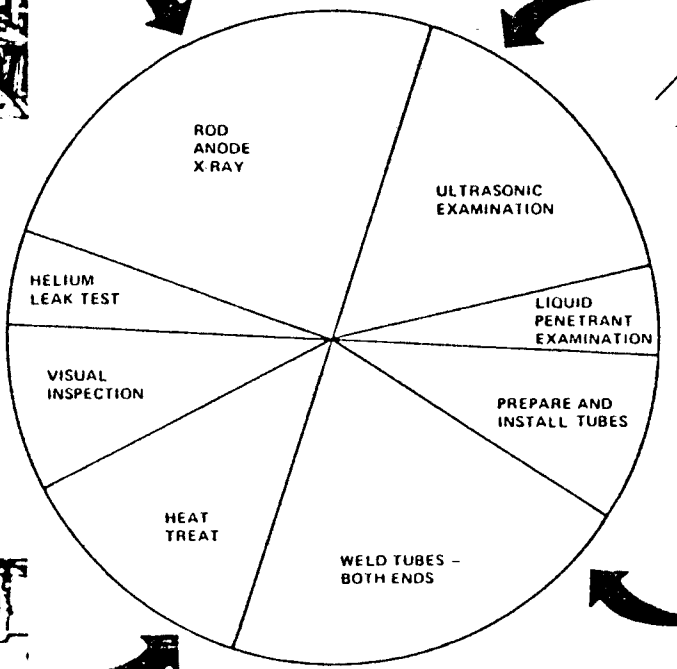
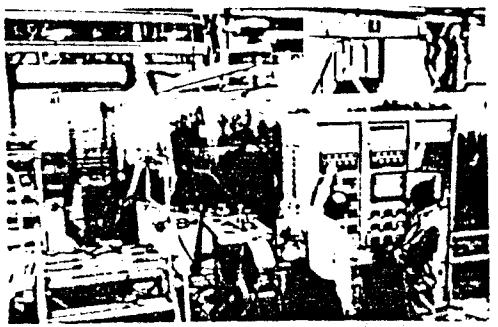
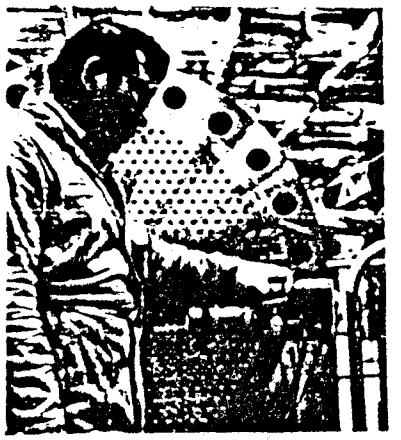
EACH WELD RECEIVES 5 SEPARATE INSPECTIONS AFTER POST WELD HEAT TREAT











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TUBE - TUBESHEET WELD ULTRASONIC INSPECTION

MICROFOCUS ROD ANODE