INTEGRAL FLOW LIMITER DESIGN FOR 700 MWE STEAM GENERATOR STEAM NOZZLE

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1.0 INTRODUCTION

The new flow limiter design, which is integral with the 700 MWe Steam Generator (SG) steam outlet nozzle, was executed to improve safety margins and reduce forces on the tubes and egg crates during a postulated Main Steam Line Break (MSLB) accident. Computational fluid dynamics (CFD) Code was used to model the complex geometry involved and calculate the pressure drop. A flow limiter is required to maximize safety margins on steam generator internal components during a hypothetical full guillotine rupture of the main steam line leading from the steam generator to the turbine generator. In addition the flow limiter limits the rate at which steam would be released inside the containment building during the progression of the event.

2.0 DESIGN OBJECTIVES

The design objectives of the integral flow limiter for 700 MWe SG are to achieve a required minimum flow area within the steam outlet nozzle to limit choked flow under accident conditions while minimizing normal operation pressure drop. These objectives are met by using seven venturi openings in the steam outlet nozzles.

3.0 MODELING DETAILS

The domain of analysis included the SG drum top, seven flow limiter venturis machined into the steam outlet nozzle and a portion of the steam pipe attached to the nozzle exit.

The flow was modeled as turbulent, compressible, single-phase flow of steam. The boundary conditions were the constant mass flow rate of 269 kg/s for normal operation at inlet and outlet pressure. For accidental conditions, the boundary conditions were the pressure at the inlet and the outlet. All walls of the steam drum, nozzle and pipe were considered to be thermally inactive and hydraulically smooth. The flow was modeled as turbulent and the k-ε model with standard wall functions was used.

4.0 GEOMETRY OPTIMIZATION

To meet the design objectives set, seven venturi openings in the steam outlet nozzles were decided after the literature survey. Various geometries were considered for the individual venturi of the nozzle. Parameters varied were the diameter and length of converging cone, throat and the diverging cone. Initially the optimization was tried in a single venturi and then assembled the optimized venturi to form the full nozzle. The geometry was optimized for reduced pressure drop during normal flow and reduced throat area for limiting choked flow. The geometry of optimized single venturi is shown in Fig.1. The cross section of the full nozzle with seven venturies are presented in Fig.2 and Fig.3. The mesh used for the analysis is shown in Fig.4.

5.0 RESULTS

The steam nozzle pressure drop during normal operation of 700 MWe SG is found to be 0.4 bar. The peak velocity in this case was limited to 168 m/s which is lower than the peak velocity (173 m/s) reported by M/s Babcock Wilcox for their SG design. The behaviour of the nozzle with respect to pressure, density and velocity are presented as contours in Fig.5 to Fig.7. The results during MSLB scenario under chocked conditions are shown in Fig. 8 to 10.

6.0 REFERNCES

1. “Testing Oconee’s Steam Generator Pressure Drop”, Simulators Section, Page 14-15, Nuclear Engineering International August 2002.

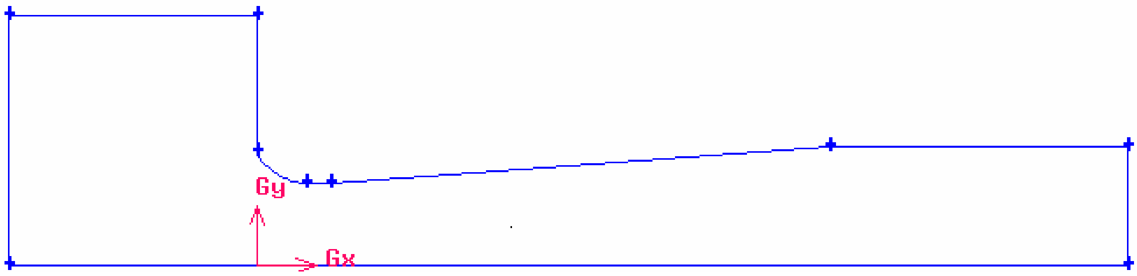

Fig.1 Optimized Venturi Profile

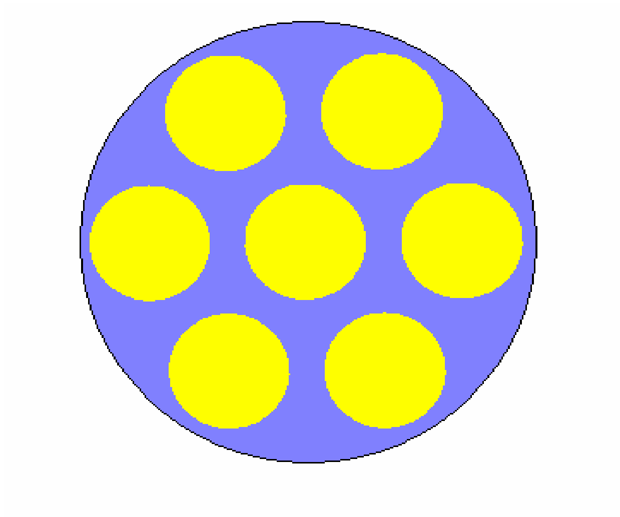

Fig. 2 Cross Section View of Flow Limiter

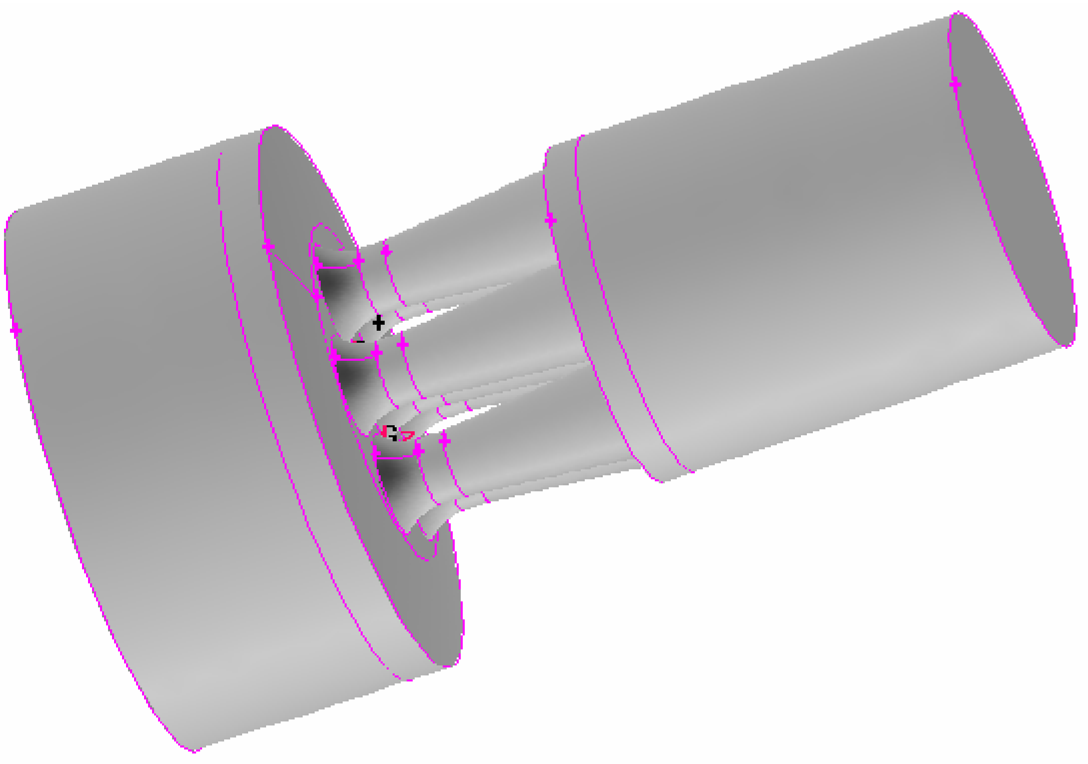

Fig. 3 Isometric View of Flow Limiter

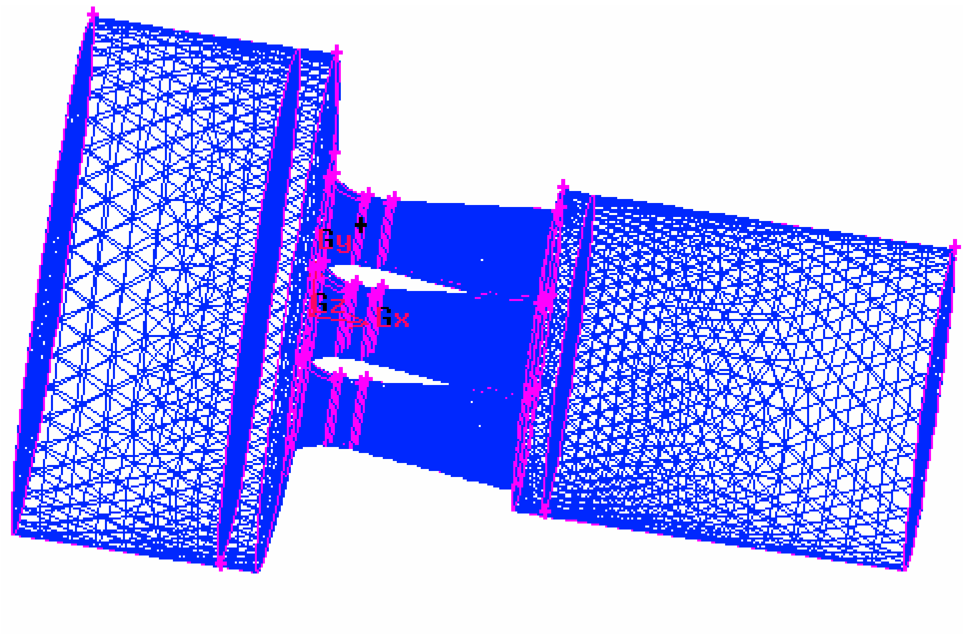

Fig. 4 Mesh Used for Flow Limiter Analysis

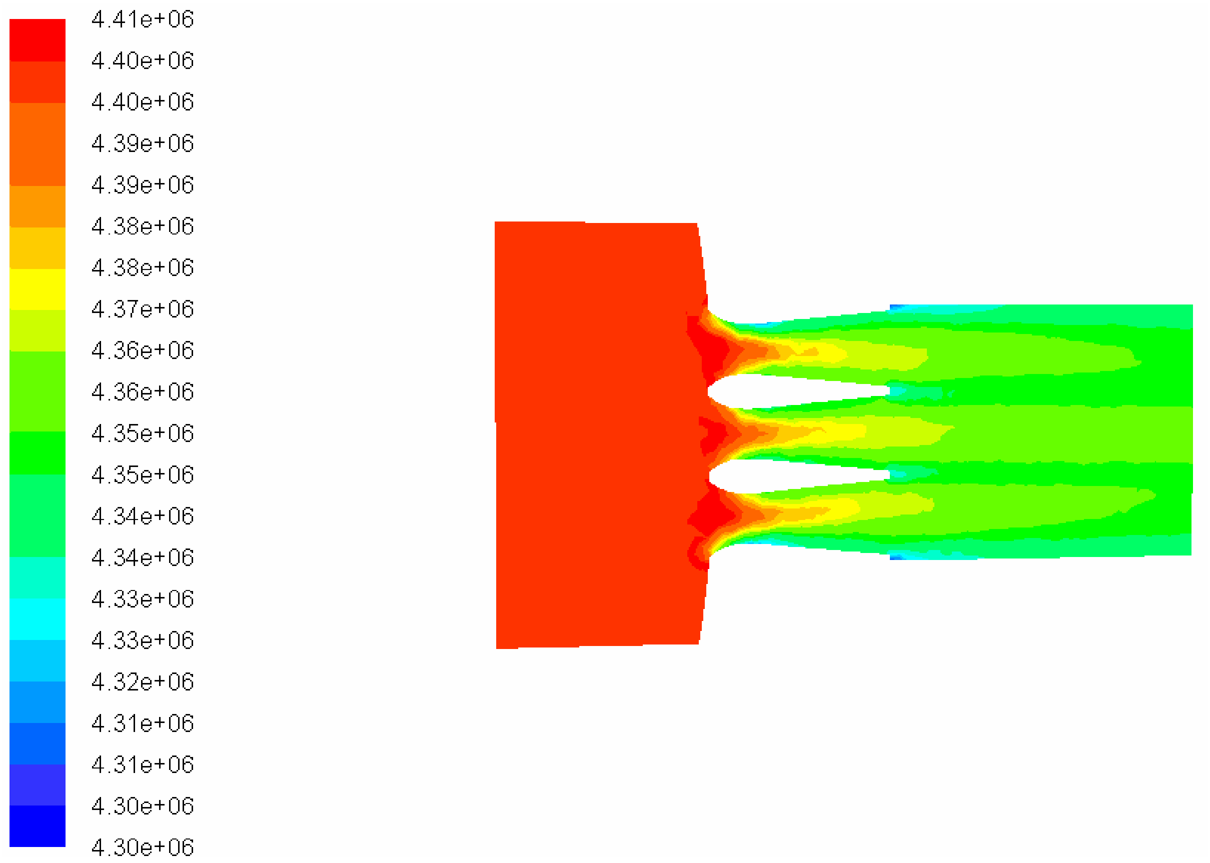

Fig. 5 Pressure Contours for 700 MWe SG Steam Nozzle During Normal Operation

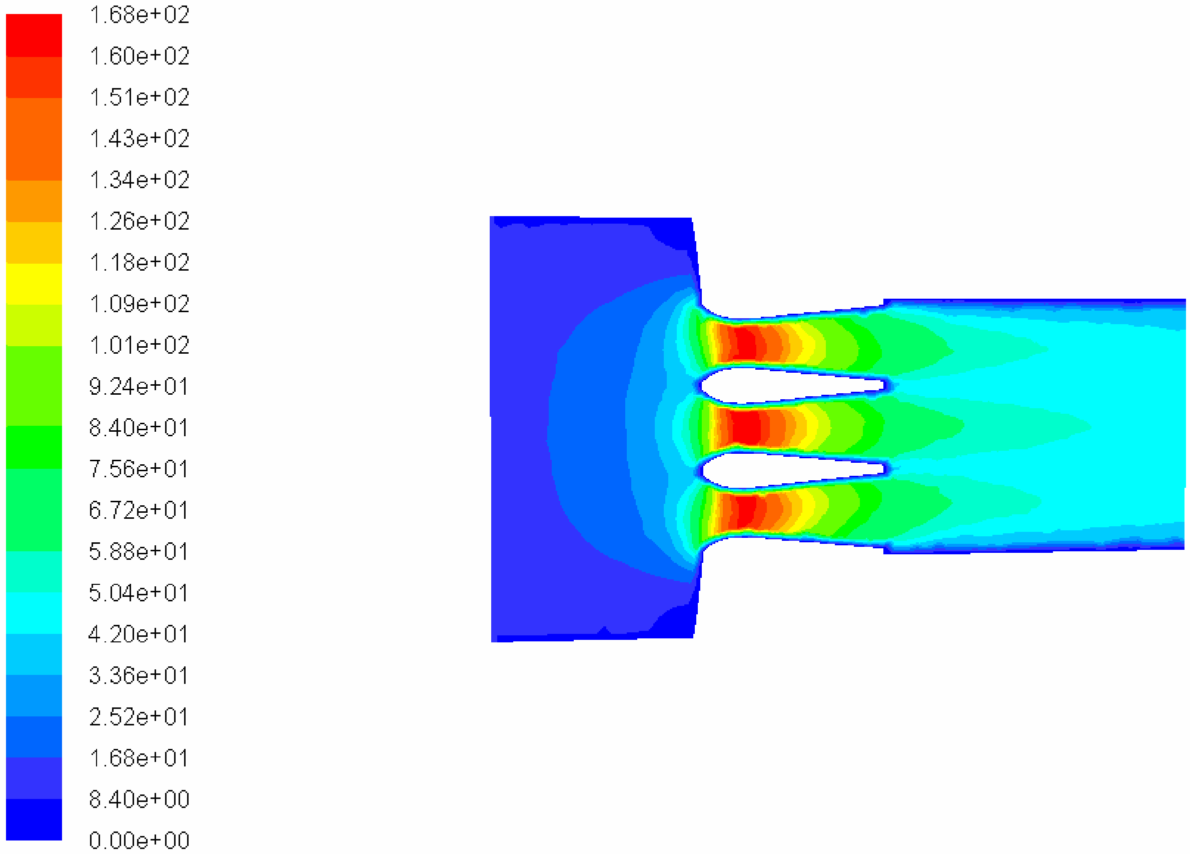

Fig. 6 Velocity Contours for 700 MWe SG Steam Nozzle During Normal Operation

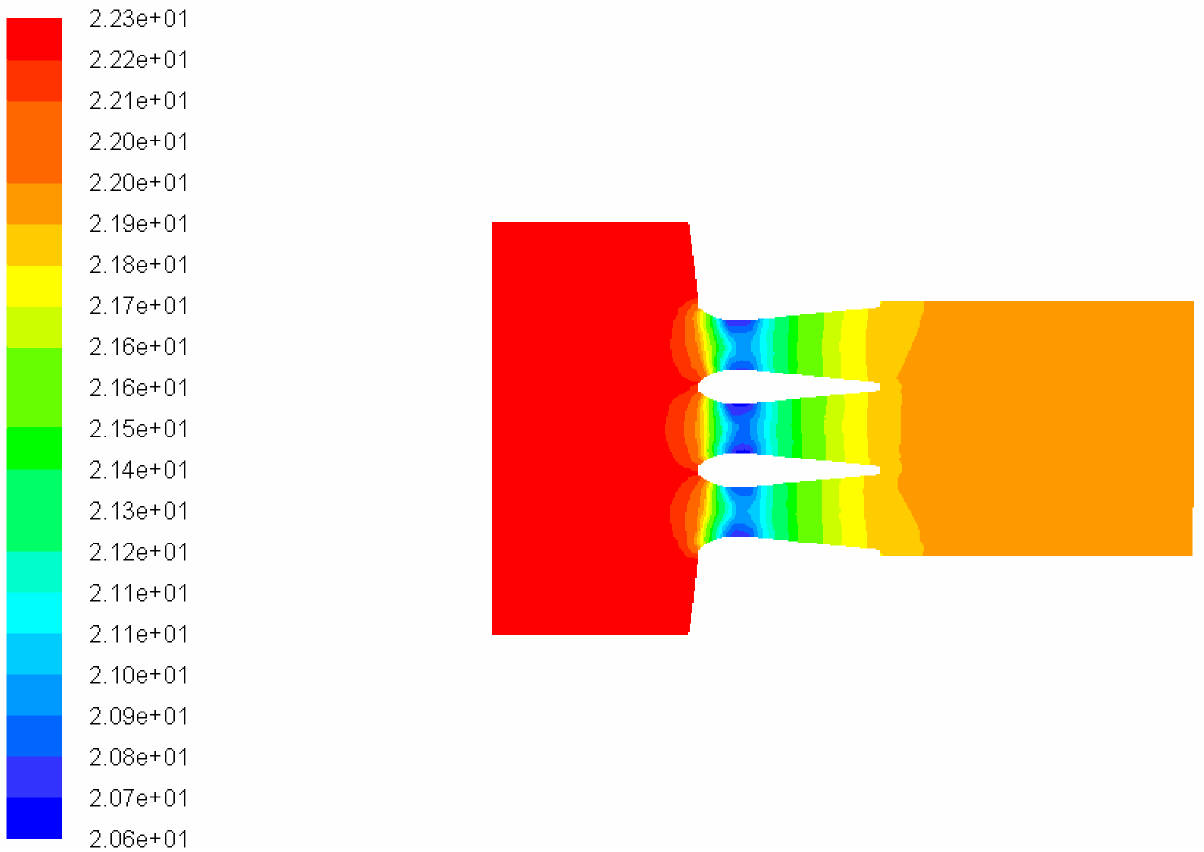

Fig. 7 Density Contours for 700 MWe SG Steam Nozzle During Normal Operation

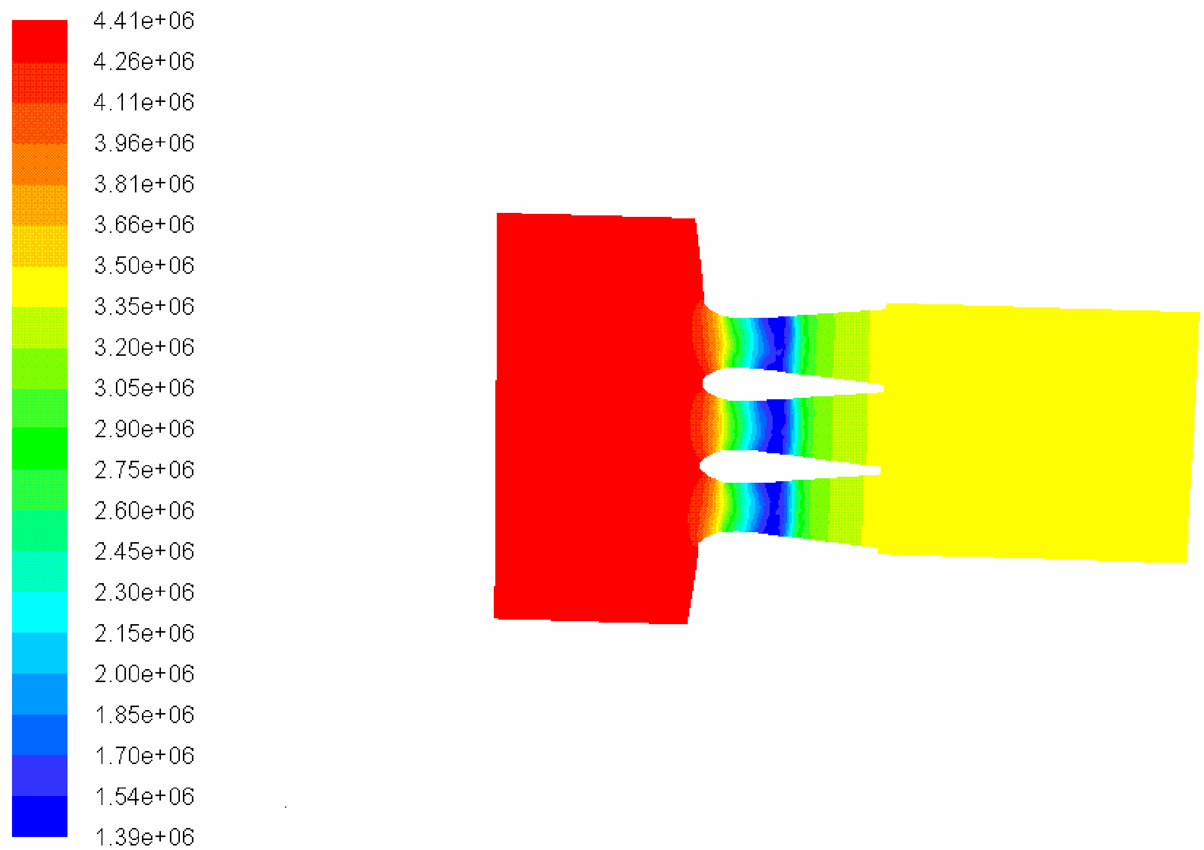

Fig. 8 Static Pressure Contours for 700 MWe SG Steam Nozzle During MSLB

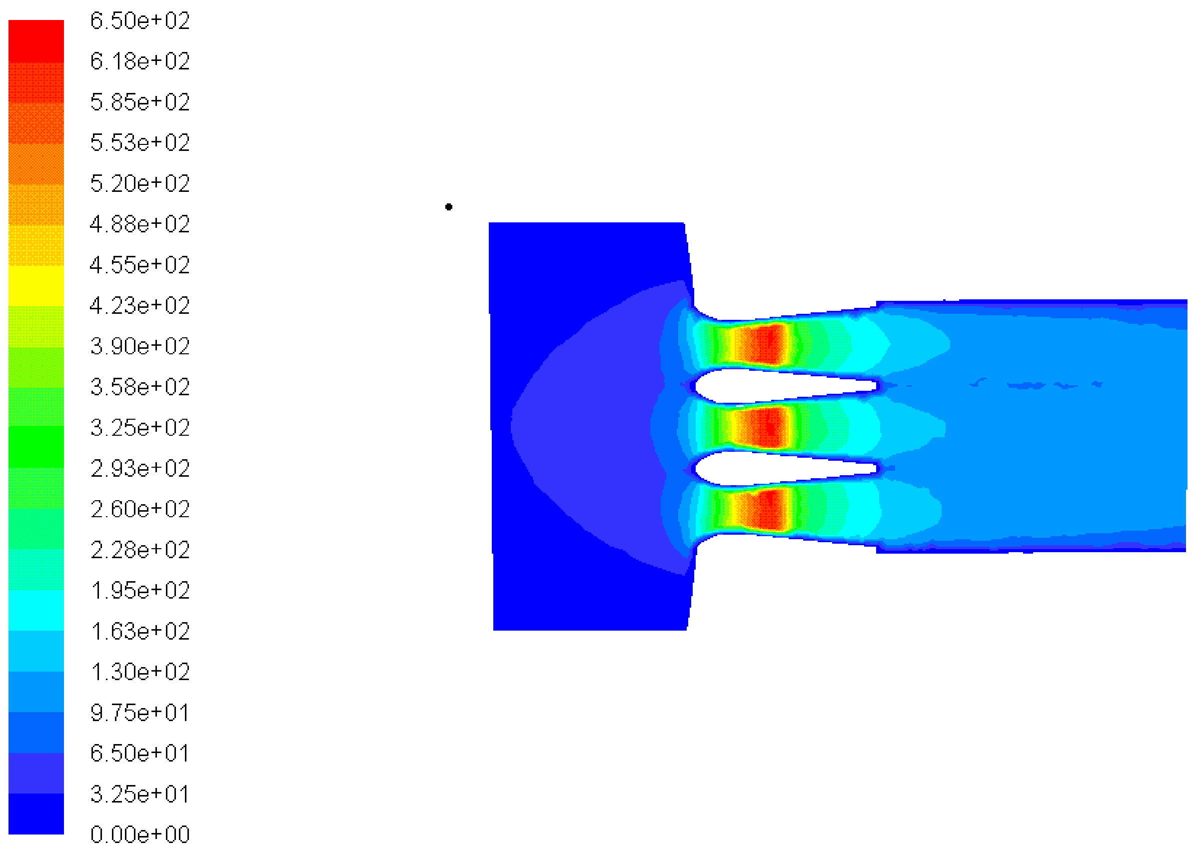

Fig. 9 Velocity Contours for 700 MWe SG Steam Nozzle During MSLB

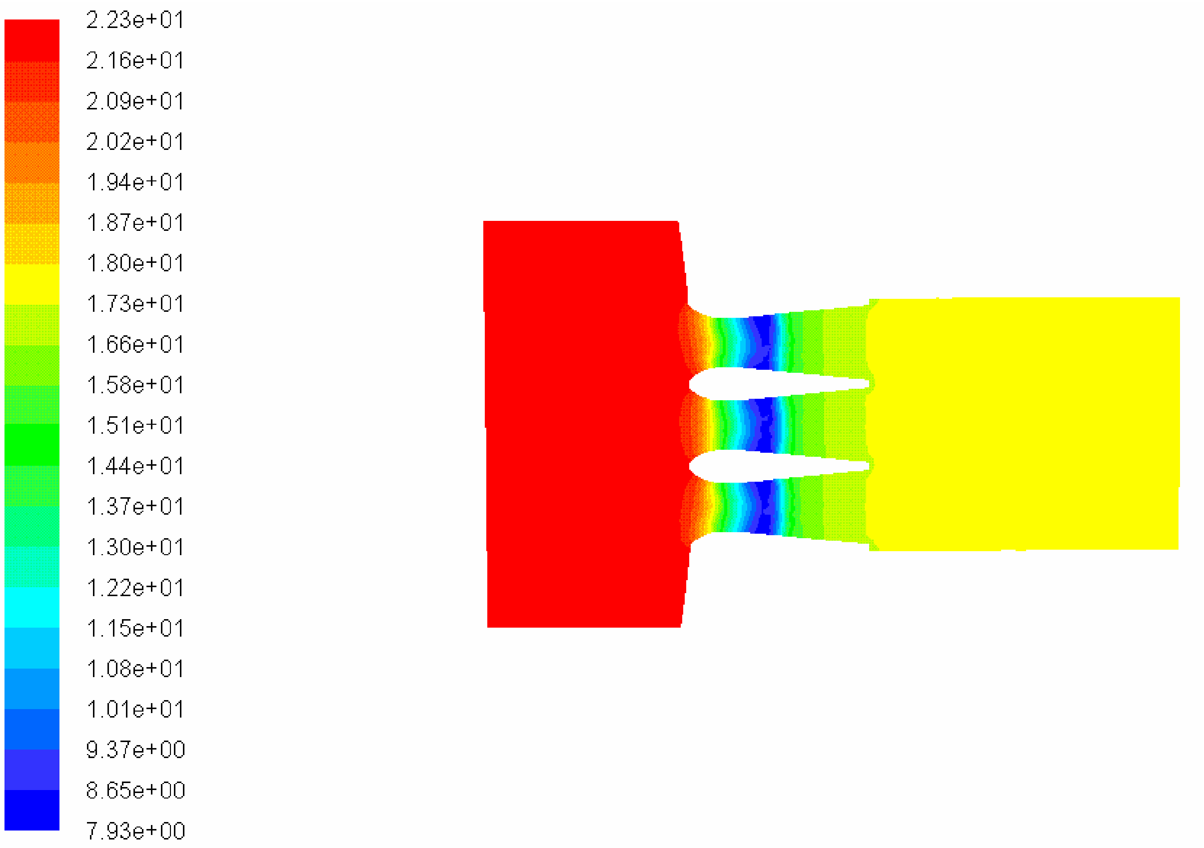

Fig. 10 Density Contours for 700 MWe SG Steam Nozzle During MSLB