# Letters to the Editor

## Comments on "Helium Production in Stainless Steel"

In a recent Note, Goel[1] makes the following comments and observations on my earlier publication.[2] His comments on my earlier paper are as follows:

1. I had pointed out the uncertainty in the data for the $^{59}Ni(n,\alpha)$ process derived from the helium production measurements.
2. The differences between the values for thermal $^{59}Ni(n,\alpha)^{56}Fe$ cross sections derived by me[2] and by Bauer and Kangilaski[3] can be due to differences in the starting values.
3. The reasons for my selection of a particular experimental point of Weitman et al.[4] and for my neglect of the data of Bauer and Kangilaski[3] are not evident from my paper.

The purpose of this Letter is to complete the above criticism of Goel.[1]

Both comments 1 and 2 stated above are correct. Regarding the third comment, I may mention here that I had felt that the experimental data of Bauer and Kangilaski could be in large error. This is confirmed by the presently[1] accepted value of $\sigma_2 = 12.5 \pm 1$ b, which is higher than that deduced in Ref. 3.

One interesting point that deserves mention regards the few related equations that Goel has explicitly avoided in his Note.[1]

Following the same notations as used in my earlier paper,[2] the correct expression (valid for both low and high fluences) for the two-step reaction is [Eq. (12) of Ref. 2]

$$N_{He}(t) = {}^{58}Ni(0)\left[\frac{\sigma_1 \exp(-\sigma_2\phi t) - \sigma_2 \exp(-\sigma_1\phi t)}{\sigma_2 - \sigma_1} + 1\right] \quad . \quad (1)$$

The corresponding expression given in Ref. 3 is

$$N_{He}(t) = \sigma_1\sigma_2\, {}^{58}Ni(0)\phi^2\left[\frac{t}{\phi\sigma_2} + \frac{\exp(-\phi\sigma_2 t) - 1}{(\phi\sigma_2)^2}\right] \quad . \quad (2)$$

The final equation used for fitting the helium production data at low fluences ($\sim 10^{21}$ n/cm$^2$) as used in Ref. 3 is

$$N_{He}(t) = \frac{1}{2}\sigma_1\sigma_2\, {}^{58}Ni(0)\cdot(\phi t)^2 \quad . \quad (3)$$

[1]B. GOEL, *Nucl. Sci. Eng.*, **69**, 99 (1979).

[2]S. GANESAN, *J. Nucl. Mater.*, **62**, 329 (1976).

[3]A. A. BAUER and M. KANGILASKI, *J. Nucl. Mater.*, **42**, 91 (1972).

[4]J. WEITMAN, N. DÅVERHÖG, and S. FARVOLDEN, *Trans. Am. Nucl. Soc.*, **13**, 557 (1970).

It is a trivial mathematical exercise to show that both Eqs. (1) and (2) reduce to Eq. (3) at low fluences. Equations (1), (2), and (3) give numerical values of $N_{He}(t)$ within 0.5% at low fluences ($\sim 10^{21}$ n/cm$^2$). However, use of Eq. (2) or (3) leads to larger errors at higher fluences, and beyond some value of the fluence, they even become physically unacceptable, i.e., $N_{He}(t)$ becomes greater than $^{58}Ni(0)$, which is not physically possible.

May I add that since the revised evaluation of $\sigma_2$ given by Goel[1] is $12.5 \pm 1$ b, the expression given in my paper[2] [Eq. (13) in Ref. 2] for the number of atoms of helium per gram of natural nickel corresponding to a thermal fluence $\phi t$ also becomes modified accordingly, as a numerical value of $\sigma_2 = 13.62$ b was used in my paper to obtain that expression [Eq. (13) of Ref. 2].

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## Remarks on "Comments on 'Helium Production in Stainless Steel'"

The earlier publication of Ganesan[1] was to explain the "fallacy in the evaluation" by Bauer and Kangilaski,[2] and it creates the impression that the low value for the thermal $^{59}Ni(n,\alpha)^{56}Fe$ cross section given by Bauer and Kangilaski is due to approximations used by them. However, it turns out that the approximations used by them are quite good[3] and the higher value of Ganesan is not due to the use of "correct" equations but due to a different data base.

In fact, the equation of Ganesan [Eq. (1) of Ref. 4] is itself an approximation. It does not account for the removal of $^{58}Ni$ or $^{59}Ni$ by processes other than those directly involved in the $^{58}Ni(n,\gamma)^{59}Ni(n,\alpha)^{56}Fe$ process. A rigorous equation has been given by Birss and Ellis[5] as

$$N_{He}(t) = {}^{58}Ni(0)\sigma_1\sigma_2\left[\frac{\exp(-\sigma_2^R\phi t)}{(\sigma_2^R - \sigma_1^R)\sigma_2^R} - \frac{\exp(-\sigma_1^R\phi t)}{(\sigma_2^R - \sigma_1^R)\sigma_1^R} + \frac{1}{\sigma_1^R\cdot\sigma_2^R}\right] ,$$

[1]S. GANESAN, *J. Nucl. Mater.*, **62**, 329 (1976).

[2]A. A. BAUER and M. KANGILASKI, *J. Nucl. Mater.*, **42**, 91 (1972).

[3]B. GOEL, *Nucl. Sci. Eng.*, **69**, 99 (1979).

[4]S. GANESAN, *Nucl. Sci. Eng.*, **72**, 121 (1979).

[5]I. R. BIRSS and W. E. ELLIS, *Proc. Br. Nucl. Soc. Conf. Voids Formed by Irradiation of Reactor Materials*, p. 339, Reading University, March 24-25, 1971, British Nuclear Energy Society (1971).