THE BENEFITS OF A LOW FLOW CONTAINMENT AND VENTILATION DESIGN APPROACH FOR NUCLEAR INSTALLATIONS

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Abstract

The Nuclear Ventilation Group of BNFL has published numerous papers in recent years expounding a new low flow design approach to containment and ventilation for nuclear buildings. This approach has been the basis of the ventilation design philosophy for a significant number of new plants built at Sellafield, Cumbria, UK since the early 1980's. The facilities designed and constructed for Sellafield are now operational and beginning to provide feedback on the success of this new design approach. The operational experience is showing that there has been no reduction in radiological safety and that the low flow designs are providing the required levels of containment and ventilation. This low flow design approach has been exported and is now being utilized by BNFL for current projects in the USA, which include the River Protection Project, Richland and AMTWP, Idaho.

The effect of the change of design approach can be seen in AECP 1054, the ventilation standard for the UK nuclear industry. In the 1979 edition of AECP 1054, the recommended air change rates were between 5/hr and 30/hr. A decade later, the 1989 edition recommended between 1/hr and 10/hr. The significance of this change becomes apparent when the extract systems of the new Thermal Oxide Reprocessing Plant (THORP) are considered. The plant has an overall airchange rate of 1.25/hr (low flow approach) and the total extract is 1.5 million m^3/hr. - a dramatic reduction when compared with the recommended airchanges of 5/hr to 30/hr.

This paper will identify the major buildings that have been constructed at Sellafield since 1980 and compare the actual design information, based on the low flow philosophy, with what the design would have been if it had been based on the recommended airchange rates given in the 1979 issue of AECP 1054. The cumulative effects from the reduction in ventilation airflows in these plants in terms of financial savings on capital for initial plant, running costs, solid and aerial waste production will be examined. In addition, the benefits

in terms of reduction of dose to workers, to the public and the reduced impact on the environment, from discharges at the plant and at the power plant, will also be discussed.

Introduction

The nuclear industry in the UK published its first code relating to ventilation design in 1979. The document was AECP 1054 [1] and it was the result of an industry wide working party and took almost a decade to produce. Around the same time BNFL was embarking on an extensive program of investment at its Sellafield plant, with new facilities and refurbishments amounting to a million pounds sterling a day for ten years. BNFL was also introducing functionalisation into its engineering, that is specialist groups. One of those specialist groups was the Nuclear Ventilation Group (NVG).

NVG was initially a mixture of ventilation specialists from non-nuclear industries and a number of nuclear engineers with a little ventilation knowledge. This group would be charged with designing the containment and ventilation for the new generation of plants for Sellafield. It set about the task by first studying and challenging AECP1054. To this end, two more working parties were initiated, the Containment and Ventilation Treatment Working Party (CVTWP) and the Filter Development and Standards Working Party. (FDSWP). These working parties invited membership from across the UK nuclear industry and discussions were held and papers prepared. Throughout the 1980's these two working parties were the forum for development of the philosophies on which BNFL based the designs of its new generation of plants. From these working parties came the low flow philosophy and circular filters.

AECP 1054 is a code of practice and as such not mandatory. In the UK, the Health and Safety Legislation covers the area of design and a designer is individually responsible for the designs produced. Compliance with a code will not alleviate any legal responsibility. AECP 1054 is the presentation of 'best practice' at the time of publication.

The CVTWP investigated containment and ventilation issues, concluding that these influenced more by plant layout than anything else. It found that ventilation was a method of reinforcing containment, but by itself it could not provide it. This finding lead to a radical re-thinking of plant layout and the part it plays in control of material migration. With a new approach to plant layout a new approach to ventilation was possible. The low flow philosophy was the result.

Low Flow Philosophy

The CVTWP continued to work throughout the 1980's (with BNFL designing its new plants in parallel) and in 1989 the second issue of AECP 1054 [2] was issued. The changes to the document were not great, but were relatively subtle and could be easily missed. The principle change was to the table of recommended air change rates. There was a very significant drop in the number of changes recommended. Table 1 is an extract from the two issues of AECP [3] and compares the recommended air change rates from 1979 and 1989. The basis for the low flow philosophy is good physical containment, good plant layout, reinforced with a low volume containment and ventilation system [3].

COMPARTMENT	1979 AIR CHANGE RATE	1989 AIR CHANGE RATE
Change rooms	4-5	4-5
Normally clean air corridors	5	1-2
Normally non-active rooms	5	1-2
Controlled areas of low potential hazard	5	2
Controlled areas of high potential hazard	10	5-10
Maintenance areas to primary containments of low risk process plants	5-10	1-5
Maintenance areas to primary containments of high risk process plants	30	10
Primary containments (glovebox, cell or cave)	2-30 depends entirely on process and hazards	30 depends entirely on process and hazards

Table 1 : The recommended air change rates given in AECP 1054 [1,2]. Columns 2 is taken from the 1979 issue and column 3 is taken from the 1989 issue.

A typical plant design based on the new philosophy is THORP, which has a total volume throughput of approximately 1.5 million m^3/hour. The average air change rate is 1.25/hour. This is a significant reduction on the recommended value in AECP 1054 when the facility was being designed, which ranged from 5 to 30. The THORP plant is a third of the size of the lowest recommended by the 1979 issue of AECP 1054, which was current at the time THORP was being designed.

Assessment of THORP

Using THORP as indicative of the other plants, the effects of the use of the new philosophy are examined. The examination includes comments on;

1 Reduced running costs for fans
2 Reduced capital cost of equipment

3 Reduced amount of radioactive waste
4 Reduced running costs for steam
5 Reduced filter waste and disposal costs
6 Reduced direct discharges to the atmosphere
7 Reduced indirect discharges to the atmosphere
8 Dose to the operators

The motor size of a system is directly proportional to the volume moved and hence if the volume were to be increased, the running costs would rise proportionately. Taking the designed THORP as having an average air change of 1.25/hour and the 1979 issue of AECP 1054 recommending 5 to 30/hour, a conservative estimate would be that the THORP ventilation plant and equipment is one third the size recommended. This is the basis of the following assessment.

Reduction in Running Costs for Fans

There are 56 major fans in THORP with a collective motor size of over 4200 kW. These are detailed in Table 2. Ignoring power factors and associated issues, the annual electricity consumption of THORP is approximately £18.5 million/annum, based on UK energy cost of 5p/kWh. The design life of THORP is twenty years and the running costs of the fans is projected to be slightly in excess of £46 million. The running costs based on the AECP 1979 recommendations (assuming an airchange rate of 5/hour) would have been nearer £132 million. The saving from using the low flow philosophy on running costs alone, is therefore £96 million.

Reduction in Capital Costs of Equipment

There are five major supply plantrooms and numerous other supply, extract and filter rooms in THORP. Lower airchange rates allows for smaller fans, ductwork, plantrooms and fewer filters. Typically this corresponds to a saving in excess of 50% on capital costs when compared against a system designed using AECP 1054 1979.

Reduction in amount of radioactive waste

License condition 32: Accumulation of radioactive waste

"The licensee shall make and implement arrangements for minimizing, so far as is reasonably practicable, the rate of production of radioactive waste accumulated".

Lower air flows need less filters, filters need to be changed and the spent filters then accumulate as radioactive waste which in turn have a knock on effect on storage costs.

Fan No	Volume (m^3/s)	No of fans operating	Motor size (kW)
R0032A/B	33.7	1	132
K0021A/B	1	1	6
K0052A/B	0.4	2	1
K0003A/B	21.7	2	90
R0028A/B	20.5	2	60
K0008A/B/C	49.1	2	215
K0010A/B	22.2	1	90
K0011A/B	19.7	1	250
K0004A/B	24.7	2	65
R0029A/B/C	92.6	3	150
K3001A/B/C	0.2	2	16
R1021/1022	0.4	2	2
K4000A/B/C	8.9	2	30
K4001A/B/C	8.9	2	110
K4002A/B/C	12.4	2	37
K4003A/B/C	14.6	2	55
K4005A/B	26.5	2	90
R0030A/B	25.6	2	75
R0031A/B	29.0	1	90
ROO33A/B	10.3	2	18
K0018	2.9	1	4
K0091A	14	1	37
K0006A/B/C	2.8	1	90
R0934A/B	3.2	1	5
K0001A/B	36	2	90
K0002A/B	9.5	2	132
R0026A/B/C	25.5	3	75
R0027	21.9	1	45
K0012 A/B	0.2	1	15
K0007 A/B/C	14.6	2	150
K0009 A/B/C	7.2	2	80
K0053	7.9	1	15
R0085	18.7	1	45
K0051 A/B	14.4	2	37
		Total Running kW=	**4205**

Table 2 Major Fans in THORP, giving kW ratings. [4]

Reduction in Running Costs for Steam

The reduced supply volume would reduce the heating requirement and hence reduce the demand for steam on the site. An assessment of this saving has not been included.

Reduced Filter Waste and Disposal Costs

THORP has 446 manual change filter elements and 178 remote change filter elements. Assume that the manual change would be low level waste (LLW) and the remote change intermediate level waste (ILW), and for a cost comparison assume the manual filters are changed every 5 years and the remote change filters every year. Disposal of LLW at Sellafield costs circa £1300/m^3, ILW costs circa £25,000/m^3 to encapsulate and a further charge of £3000/m^3/annum storage, and Plutonium Contaminated Waste £12,500 per 500l drum. Thus THORP filter disposal costs can be calculated as being approximately £178,500,000 over twenty five years. The comparison with the recommended would be £714,000,000

Reduced Direct Discharges to the Atmosphere

The off-gas cleaning of gaseous effluent can be very expensive, but a figure will not be put on savings of discharges to the atmosphere. The Sellafield site license is not related to the size of plant, but to the allowable discharges with respect to acceptable dose to the general public and the environment. Thus bigger plants would have required additional cleanup kit to allow the discharges meet the license limits. The cost of cleaning the additional cleanup kit is not included in the assessment.

Reduced Indirect Discharges to the Atmosphere

Prior to the construction of THORP and the other plants in Figure 1, Sellafield site consumed in excess of £20 million of electrical energy per annum for operating fans. To meet this demand BNFL operates Calder Hall nuclear power station. The station is a Magnox station and is expected to be decommissioned in the near future. Designing the new plants to the AECP 1054 recommendations would have required an increase in power supply of 12.6 MW. Depending on the method of generation, this would have increased the CO_2 discharges to the atmosphere by around one million tonnes over twenty years. A monetary value of this saving is not being claimed here, though the environmental impact of such a reduction of an important greenhouse gas must be considered as significant.

Dose to the operators

The dose targets in the UK are derived initially from ICRP 26 [4], ICRP 30 [4]. The latest limits are based on ICRP 60 [5]. The design of THORP began in the early 1980's and in 1985 the Ionizing Radiation Regulations (IRR's) became law in the UK. These limited the dose to workers to 50 mSv/yr and to the general public to 5 mSv/yr. In 1999 there was a revision to the IRR's, with the new limits being 20 and 1 mSv/yr respectively.

BNFL operates its plants to targets well within the legal limits. The dose to operators and the general public from the new generation of plants is a step change down on the older plants. Thus the low flow philosophy has not compromised the dose to operators, the combination of revised plant layouts, remote operation of plants and improved understanding of containment and the role played by the ventilation system has led to a significant decrease in the dose to operators.

Comparison with Other Plants

The investment program of the 1980's did not just produce THORP, many other plants have been constructed. These plants are related to waste handling on Sellafield site Figure 1 gives the major plants. A conservative estimate would be that these other plants combined, constitute a second THORP and hence the savings calculated above can be readily doubled. The calculations above are an order of magnitude only.

Discussion

The intent of this paper is not to present accurate calculations of the exact savings made from developing the low flow philosophy, but to present an indication of the impact that the new philosophy has had in the UK. The reduction in capital costs of plant, equipment and building space, the reduction of running costs from electricity, steam and filter consumption are all significant financial savings for BNFL and yet the greater impact is in less obvious areas.

The UK disposes of LLW by burial at Drigg. There is a finite size to Drigg and waste compaction is utilized to minimize waste. A reduction in waste production makes far more efficient use of the space available. For ILW, the UK does not have a final disposal repository at present and hence, all wastes being produced are held in interim storage. The reduction of solid wastes from plants has meant the number of interim stores required is less. The cost of providing increased interim stores is financial of course, but space to build is a problem, as is operating these stores and ultimate decommissioning are other factors for consideration.

The reduction in energy consumption at Sellafield is also significant, as the chosen source of replacement power for Calder Hall nuclear power station is a gas fired CHP plant. Maximum efficiency is obtained from the fuel source in a CHP plant, but this is only viable if the steam and electricity consumption can be matched. The match may not have been achievable if the plants had been designed to the AECP 1054 recommendations.

Greenhouse gas emissions are an international discussion topic, with heads of state summits being arranged to discuss reductions. The UK government has a target for a 20% reduction of CO_2 emissions by the year 2010. BNFL has, by adopting the low flow philosophy and choosing not to build bigger plants, contributed significantly to CO_2 emission reductions in the UK. The new plants are effectively a reduction of at least two million tonnes of CO_2 brought about at the design concept stage.

The dose to the operators and the general public are the real test of how successful the adoption of the new philosophy has been. The dose to operators in the new plants is significantly reduced when compared with the dose in older plants at Sellafield. The overall aerial discharges from Sellafield during the period of new build, have been falling and are continuing to do so.

Conclusion

The new generation of nuclear plants designed to the new philosophy are proving to be very successful in operation. The adoption of the low flow philosophy has had significant impact on BNFL and the UK. The benefits will continued into the future, right through to decommissioning, when smaller plants will be required to be disposed of. This approach to design is now current practice within BNFL and the plants designed by BNFL have these inherent features within them.

References

1 AECP 1054 1979
2 AECP 1054 1989
3 Low Flow Containment And Ventilation Design For Nuclear Installations R Doig DOE/NRC Conf. 1998
4 THORP Technical Manual
5 Internal paper (not published), Pond 5 energy savings, Robert Scattergood

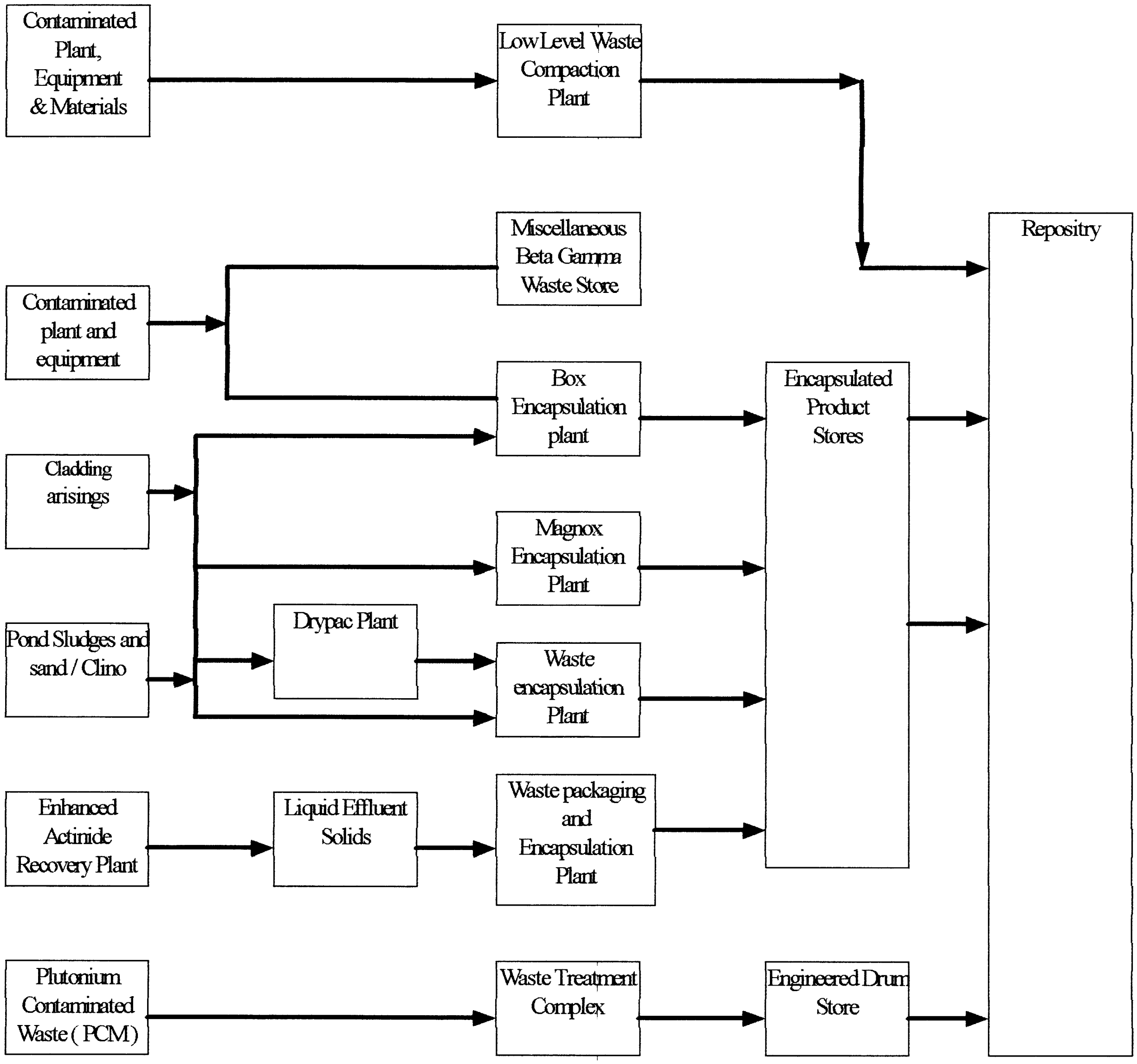

Figure 1 New plants designed to low flow ventilation philosophy