SESSION XII

REGULATION

Thursday, August 31, 1972
CHAIRMAN: R. W. Zavadoski

USE OF AIR CLEANING SYSTEMS AT NUCLEAR POWER STATIONS TO MEET LOWEST PRACTICABLE LIMITS N. Thomasson

CHAIRMAN'S OPENING REMARKS:

As you know, the proposed Appendix I to Part 50 of Title 10 of the Code of Federal Regulations has drastically changed the role of air cleaning systems in nuclear power plants. The paper to be presented today by Dr. Thomasson ties together all the parameters used in meeting the proposed Regulations. By following the methodology of this paper, a determination can be made of whether or not an air cleaning system is required to meet the regulations.

Dr. Thomasson, a former member of the Atomic Energy Commission, and presently in the Environmental Protection Agency, gives an excellent summary of the respective roles of the Environmental Protection Agency and the Atomic Energy Commission.

USE OF AIR CLEANING SYSTEMS AT NUCLEAR POWER STATIONS TO MEET LOWEST PRACTICABLE LIMITS

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ABSTRACT

The principles of "low as practicable" are now being applied to radioactive effluents from commercial nuclear power reactors. The United States Atomic Energy Commission has proposed numerical guidance to what may be "low as practicable" in its proposed Appendix I to 10 CFR Part 50.36a. The proposed limitations on the discharge of ^{131}I are the most restrictive criteria. In order to evaluate the capability of a nuclear power plant to meet the proposed iodine concentration limits, input data (coolant fission product concentrations, leak rates, partition factors, and filter efficiency) must be available to obtain estimates of iodine discharges to the environment. Because of the lack of operational data regarding these parameters, it is necessary to make conservative assumptions. As a result, it is clear that, based on the conservative assumptions, light-water reactors will have problems in meeting not only Appendix I limits, as proposed, but, also, the presently applied limits when there are multiple reactors at a site and/or when there is poor atmosphere dispersion at a site.

INTRODUCTION

In 1959 the United States Congress established the Federal Radiation Council (Public Law 86-373), which was delegated the responsibility to provide a Federal policy on human radiation exposure(1). A major function of the Federal Radiation Council (FRC) was to provide guidance to all Federal agencies in the formulation of radiation standards. The FRC in its initial staff report expressed the philosophy that every reasonable effort should be made to maintain radiation exposures as low as practicable below any established standard. In accordance with the President's Reorganization Plan Number 3 of 1970, the functions of the FRC were transferred to the Environmental Protection Agency (EPA) on December 1, 1970. EPA is currently reviewing the previous guidance provided by the FRC regarding "low as practicable" concepts. Until the EPA review is completed, EPA is following the existing guidance.

On December 2, 1970, the United States Atomic Energy Commission (AEC), published new rules - Title 10 of the Code of Federal Regulations, Parts 50.34a and 50.36a, which require light-water nuclear reactors (LWRs) to be constructed and operated such that radioactive discharges to the environment during normal operation will be "as low as practicable." On June 13, 1971, the AEC published the proposed Appendix I to 10 CFR Part 50.36a, which defined "low as practicable" in numerical terms.

Appendix I, as proposed, provides guidance for liquid and gaseous discharges of radionuclides and for annual dose rates to individuals. The proposed (and present) atmospheric concentration limits for ^{131}I are the most restrictive discharge criteria which utilities have to meet. For example, the proposed rule states that the release of halogens and particulates with half-lives greater than 8 days should be limited to one-one hundred thousandth (1/100,000) less than current concentration limits for unrestricted areas, as given in 10 CFR Part 20, Table II, Column 1. Furthermore, current nuclear power plant discharge limits(2), included in the technical specifications of operating nuclear power plants, generally restrict annual average ^{131}I discharges to 1/700 of the limits given in 10 CFR Part 20, Table II, Column 1, or to 1.43×10^{-13} Ci/m^3, at the site boundary. The AEC is presently conducting rule making proceedings which are directed at establishing an AEC regulation defining "low as practicable" discharge limits for LWRs. Until the proceedings are completed and the results formalized as AEC regulations, the numerical guidance provided in Appendix I to CFR Part 50.36a is being used as a definition of "low as practicable." Because of the potential problems in meeting the "low as practicable" guidance for ^{131}I discharges, the potential sources of ^{131}I and the iodine control technology and practices are emphasized in this paper.

GASEOUS EFFLUENTS FROM COMMERCIAL NUCLEAR POWER PLANTS

General

One approach to evaluating the expected atmospheric discharges from the operation of a nuclear power plant is (1) to identify the possible effluent release points, (2) to estimate the discharge rate of radionuclides from each source, and (3) to compare the resulting atmospheric concentrations with established limits or guidelines. In pursuing this methodology, estimates must be made of (1) fission product inventories in the reactor coolant, (2) reactor coolant leak rates, (3) isotopic partition factors between the coolant, steam, and/or air, (4) filter system efficiency, and (5) atmospheric dispersion of the effluents. A given nuclear power plant is expected to operate for 30 to 40 years, and operation over any particular year is expected to be characterized by a spectrum of operating parameters (e.g., power level, fission product inventories, leak rates, coolant purification rates, and iodine partition factors). Therefore, in order to simplify the analyses, representative steady-state values (average values) may be estimated. The results of the evaluation can then be applied to determine if additional effluent control systems are necessary to attain, with reasonable assurance, established effluent concentration limits or guidelines. In making such determinations, it is desirable to use as realistic assumptions as possible so that equipment needs can be correctly specified.

The purpose of this paper is to assess the capability of current air cleaning technology and practices to control the discharge of radioactive materials from LWRs. In order to make such an assessment, it is necessary to (1) quantify the gaseous discharges, giving special attention to iodine releases (as noted above); (2) describe current control practices and their possible improvements; and (3) compare the effectiveness of current practices and technology against criteria such as Appendix I.

Assumptions for Effluent Estimates

The best source of data for evaluating expected plant releases would be from operating reactors. However, there is a scarcity of data related to coolant fission product inventories, coolant leak rates, and iodine partition factors. Consequently, it is necessary to make conservative assumptions which are somewhat arbitrary. The parameters used in making the analyses for this evaluation are based largely on source terms given in selected utilities safety analysis reports and/or used by the AEC in its environmental impact statements. These assumptions and their sources are detailed in Appendix A and Appendix B.

The one assumption which is not referenced is the assumed iodine release fraction following a coolant leak in the auxiliary building of a pressurized water reactor (PWR). The release fraction assumed is midway between a less conservative value employed by the AEC in its environmental statements [3] and a more conservative value used by Rodger [4] in his testimony at the AEC rule making proceedings regarding "low as practicable" effluent limits. The AEC assumption is based on leakage of depressurized, cold coolant, while Rodger's intent is to provide margin in plant system design.

In order to make realistic estimates of ^{131}I discharges from LWRs, information is needed to characterize (1) coolant fission product concentration, (2) coolant leak rates into the containment, auxiliary building, steam generators, reactor building, and turbine building, (3) pressure and temperature characteristics of the leaking fluid, (4) steam generator operating characteristics--blowdown and steaming rates, (5) iodine concentration in the effluents, (6) exhaust flow rates, and (7) in-place charcoal filter efficiencies. From these measurements, estimates can be made of the overall iodine release fractions (ratio of iodine discharge to the environment to iodine in the coolant from the leaking source). This ratio would include mechanisms such as plateout, washout, condensation, and those mechanisms covering gas-liquid partitioning to the environment following a coolant leak.

Effluent Sources

Table 1 and Table 2 present tabulations of the estimated gaseous ^{131}I effluents from various points for a typical boiling water reactor (BWR) and a typical PWR, based on the assumptions given in the attached appendices. The tables also indicate the remaining ^{131}I discharges following the sequential addition of effluent control systems to the various discharge points.

As indicated in Table 1, the most important effluent release point for ^{131}I discharges for currently operating BWRs is the steam jet air ejector, which discharges through a nominal 30-minute decay pipe to an elevated (∿100 meter) stack. Other sources of ^{131}I discharge from BWRs are (1) steam leakage, primarily in the turbine building, (2) turbine gland-seal leakage, and (3) reactor building releases from normal ventilation and periodic containment purges. Figure 1 illustrates the various plant gaseous effluent points and some of the potential sources of iodine to each.

TABLE 1

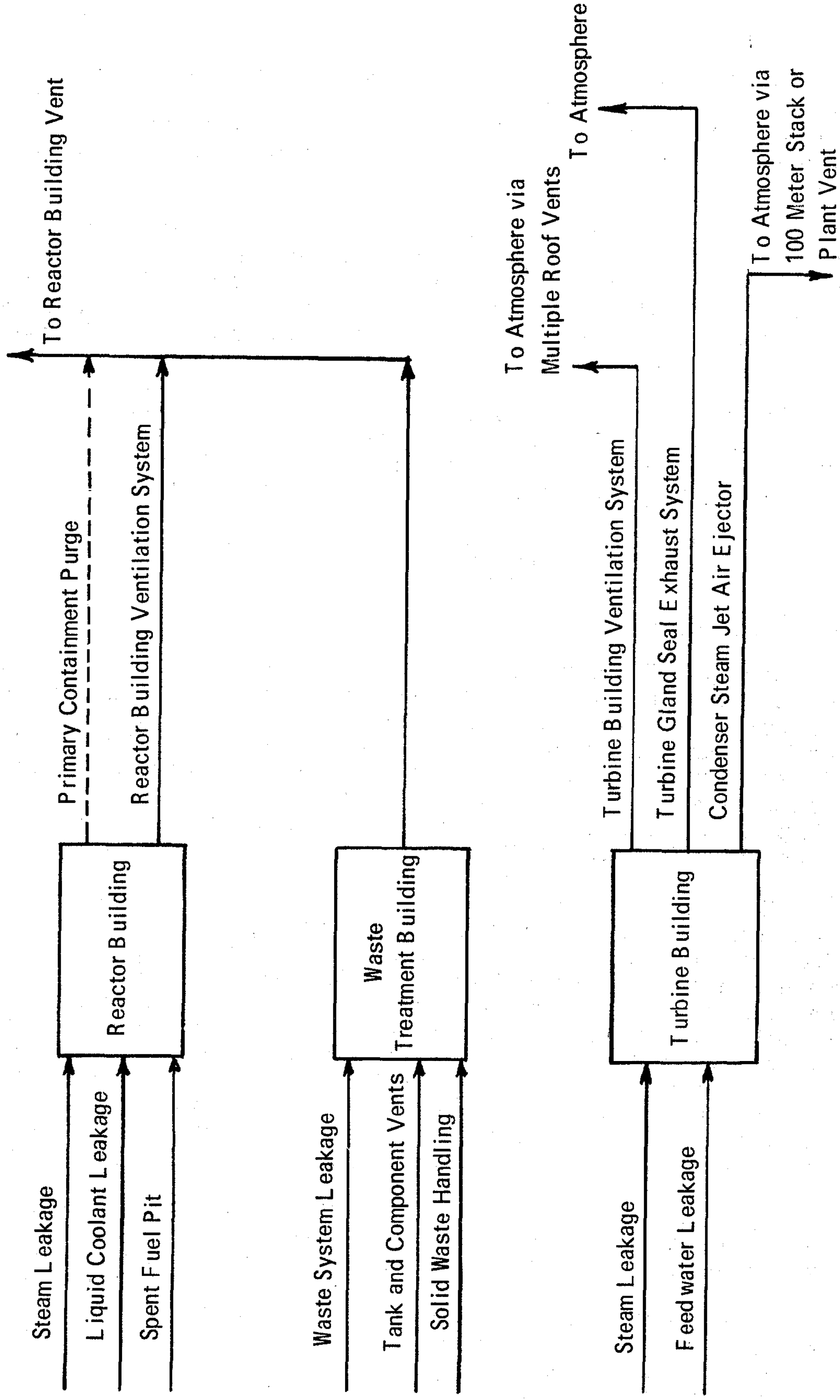
CALCULATED BWR ^{131}I ANNUAL RELEASE RATES

Control System Added	Condenser Air Ejector Ci/yr	Turbine Building Ci/yr	Turbine Gland-Seal Ci/yr	Reactor Building Ci/yr	TOTAL Ci/yr
None	193	6.2	3.9	0.1	200
Condenser Off-Gas Treatment (Deep-Bed Charcoal or Cryogenic)	∿0	6.2	3.9	0.1	10
+ Turbine Building Charcoal Filters	∿0	0.06	3.9	0.1	4
+ Clean Steam Gland-Seal	∿0	0.06	0	0.1	0.2
+ Reactor Building Charcoal	∿0	0.06	0	∿0	0.1

TABLE 2

CALCULATED PWR ^{131}I ANNUAL RELEASE RATES

Control System Added	Auxiliary Building Ci/yr	Containment Purges Ci/yr	Steam Generator Blowdown Tank Ci/yr	Condenser Air Ejector Ci/yr	TOTAL Ci/yr
None	0.1	0.3	0.38	0.15	0.93
Auxiliary Building Charcoal Filters +	0.001	0.3	0.38	0.15	0.83
Containment Purge Charcoal Filters +	0.001	0.003	0.38	0.15	0.53
Blowdown Tank Vent Charcoal Filters +	0.001	0.015	0.004	0.15	0.17
Condenser Air Ejector Charcoal Filters	0.001	0.003	0.004	0.002	0.01



NOTE: Dash Lines Indicate Periodic Sources

Figure 1

IODINE SOURCES FROM BOILING WATER REACTORS

The only potential source of continuous iodine release for PWRs is the auxiliary building ventilation system. This building contains the chemical and volume control system (CVCS), the boron management system (BMS), liquid and gaseous waste processing systems, and the spent fuel storage area; all are potential sources of iodine leakage.

PWRs, which control the chemistry of the secondary coolant by discharging (blowing down) a portion of the secondary coolant to a tank (blowdown tank), release ^{131}I to the environment through the blowdown tank vent whenever there is primary-to-secondary coolant system steam generator tube leakage. Another secondary coolant system release point is the condenser steam jet air ejector.

Periodically, a few times a year, the PWR containment is purged in order to allow plant personnel extended access. The ^{131}I in the containment originates from small primary coolant system leaks. Figure 2 illustrates the PWR release points and the significant potential iodine sources for each.

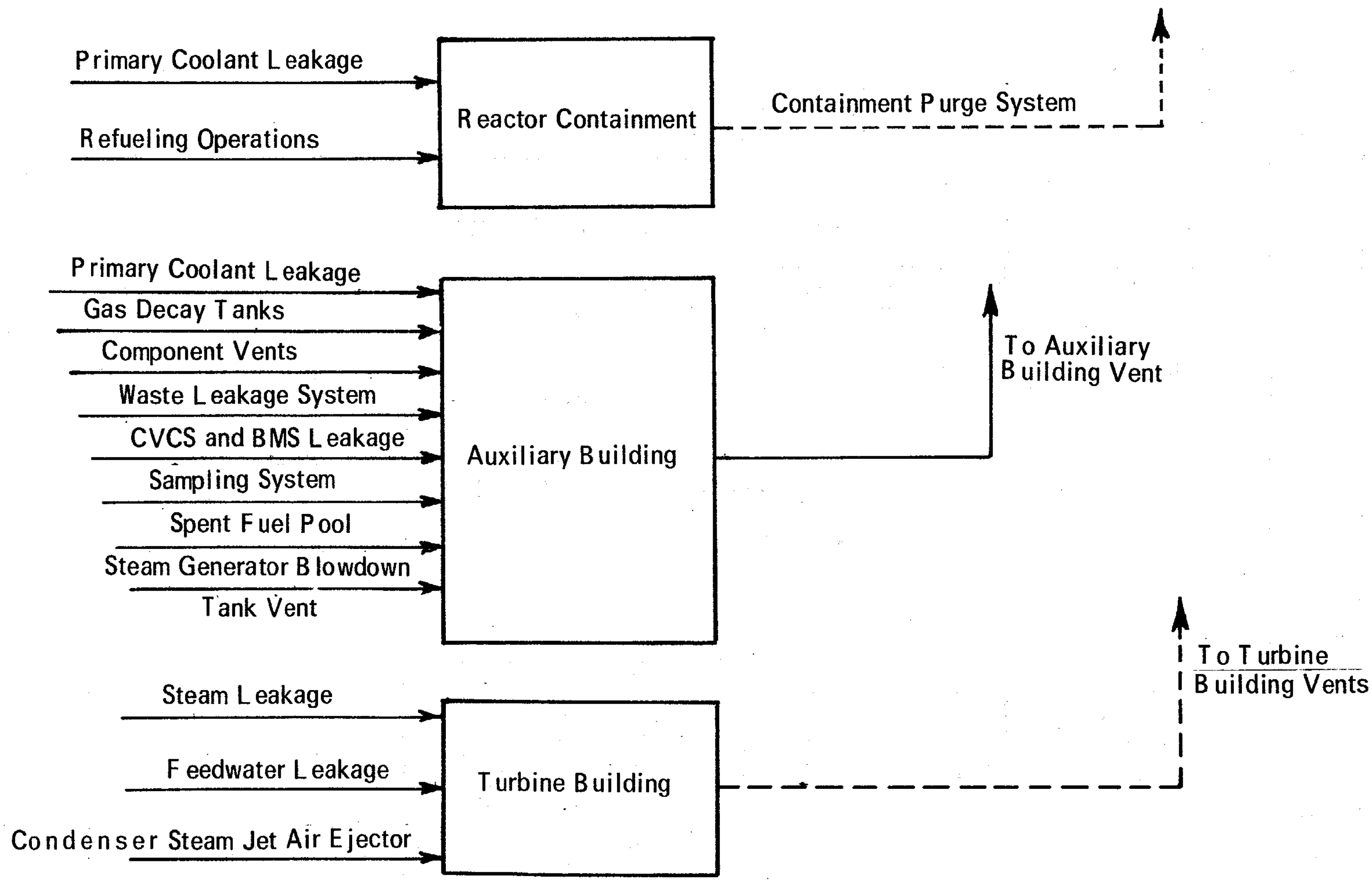
IODINE CONTROL SYSTEMS

Boiling Water Reactors

Typical BWR iodine control systems are shown in Figure 3. The only charcoal filter system normally included is in the standby gas treatment system (SGTS), which is an engineered safety feature. If necessary, the SGTS can be used to control iodine discharges from the reactor building, including containment (drywell) purges. As shown in Table 1, however, this source is expected to be a minor contributor to the total ^{131}I releases. One plant[5] with high population densities around it has proposed an internal recirculation type charcoal filter system for the containment drywell.

The annual discharge of ^{131}I from future (and some operating) BWR condenser steam jet air ejectors is expected to approach zero, since these BWRs will have condenser off-gas control systems for reducing noble gas releases, which are expected to control iodine as well. For example, control systems such as deep-bed charcoal delay columns[6], cryogenic distillation systems with charcoal filters on the vent path[5], and pressurized decay tanks preceded and followed by charcoal filters[7] have been proposed. In general, the deep-bed charcoal delay columns have been the most commonly proposed system. Largely as a consequence of the addition of condenser off-gas control systems, elevated stacks at BWRs are being eliminated; thus, gaseous releases at most new BWR facilities will probably be from plant vents.

Even though the major source of ^{131}I discharges will effectively be eliminated through the use of condenser off-gas control technology, BWRs will have to reduce the potential releases from the turbine building and the turbine gland-seal systems if they expect to reach the discharge levels indicated in Table 3, using the assumed conservative parameters. To my knowledge, no plant has yet proposed to provide charcoal filtration for the turbine building ventilation system. Provision of such a system would probably require major redesign of the currently proposed (and operating) systems which incorporate multiple vent points. Similarly, no charcoal filter system has been proposed



NOTE: Dashed Lines Indicate Periodic Sources

Figure 2

IODINE SOURCES FROM PRESSURIZED WATER REACTORS

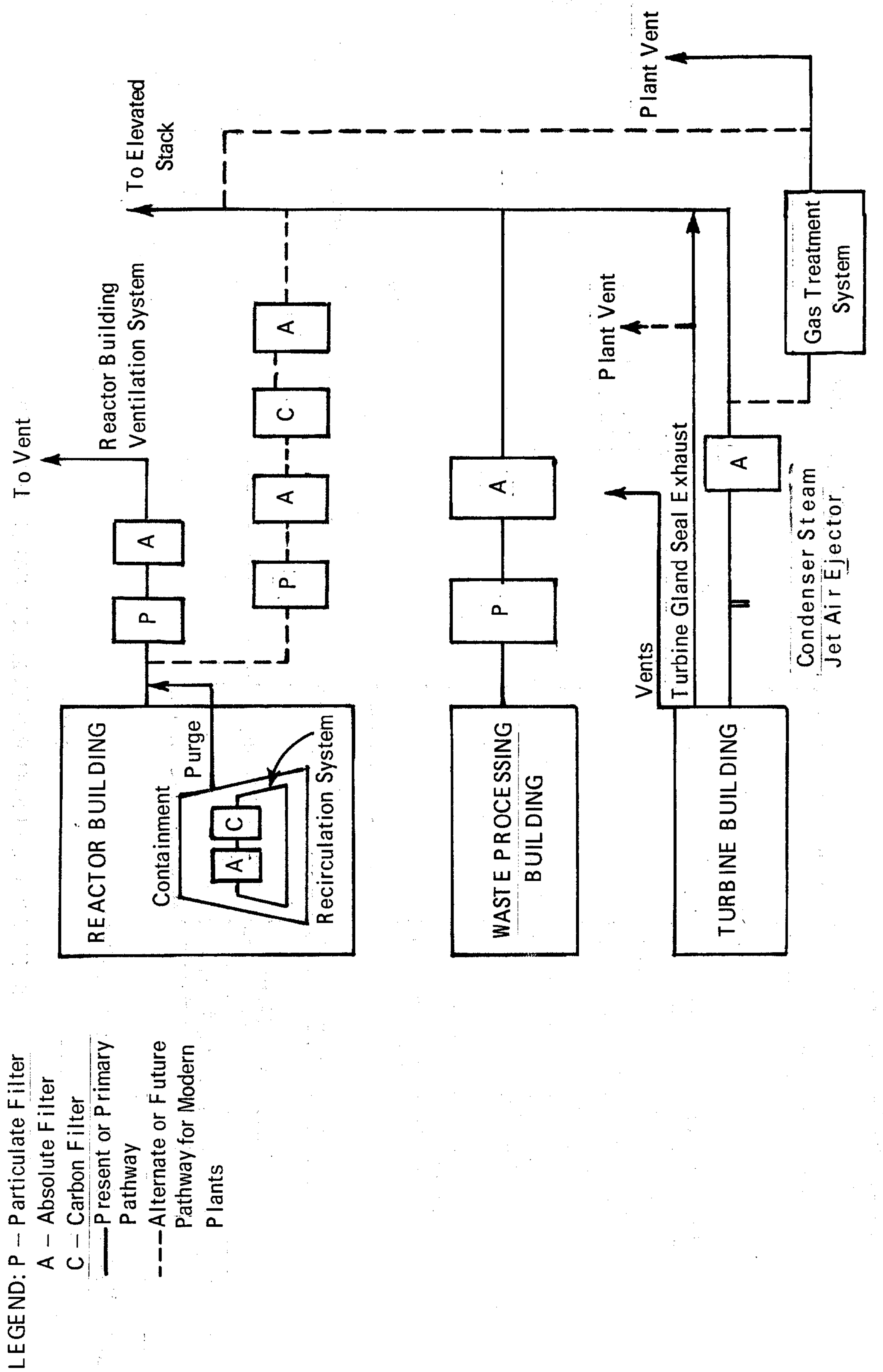


Figure 3

BOILING WATER REACTOR IODINE CONTROL SYSTEMS

TABLE 3

ANNUAL AVERAGE ^{131}I RELEASE RATE LIMITS

Guide	Vent* Ci/yr	100 Meter Stack** Ci/yr
10 CFR Part 20 (10^{-10} Ci/m^3)	3,200	160,000
10 CFR Part 20 with 700 reconcentration factor (1.43×10^{-13} Ci/m^3)	4.7	240
Proposed Appendix I (10^{-15} Ci/m^3)	0.032	1.6

*For an annual average atmospheric dispersion factor of 10^{-6} sec/m^3.

**For an annual average atmospheric dispersion factor of 2×10^{-8} sec/m^3.

for the turbine gland-seal steam releases. However, at least one plant[5] has proposed using a clean steam system for this purpose rather than using process steam, i.e., steam produced in the reactor.

Pressurized Water Reactors

A large fraction of currently proposed PWRs have containment internal recirculation charcoal filters and/or single-pass containment purge charcoal filters. In addition, some plants have proposed charcoal filters for the auxiliary building[8,9,10]. The majority, however, only utilize charcoal filter systems for selected area ventilation control, such as for pump and heat exchanger rooms[11,12]. It is apparent, based on the conservative values indicated in Table 2, that if the PWR is to achieve ^{131}I discharges comparable to those shown in Table 3 for vent releases, provisions will have to be incorporated to reduce or to eliminate ^{131}I discharges from the steam generator blowdown tank vent, the condenser steam jet air ejector and, possibly, the auxiliary building ventilation system. Typical PWR iodine control systems are illustrated in Figure 4.

CONCLUSIONS

BWRs and PWRs may have to use the best available technology if they are to meet the concentration limits for ^{131}I as currently proposed in Appendix I. Reactors situated on sites with poor atmospheric dispersion characteristics will have a problem meeting the ^{131}I discharge limits now in effect. Furthermore, since the present and proposed ^{131}I atmospheric concentration limits are for total site discharges, utilities with multiple reactors at a given site will encounter significantly greater problems in meeting the applicable discharge limits.

Since there is little operational data available to estimate the expected ^{131}I discharges from LWRs, the only reasonable alternative left to regulatory agencies, environmental agencies, and health officials is to use conservative assumptions in establishing source terms and expected releases. As a result, utilities may find it necessary to provide expensive iodine control systems in order to demonstrate that there is a reasonable probability of operating within the applicable discharge limits. On the other hand, if operational data, including coolant concentrations, leak rates, iodine release rates, and other pertinent information were available, less conservatism would be required in making the assumptions, and the installation of air cleaning equipment which is not actually needed could be avoided.

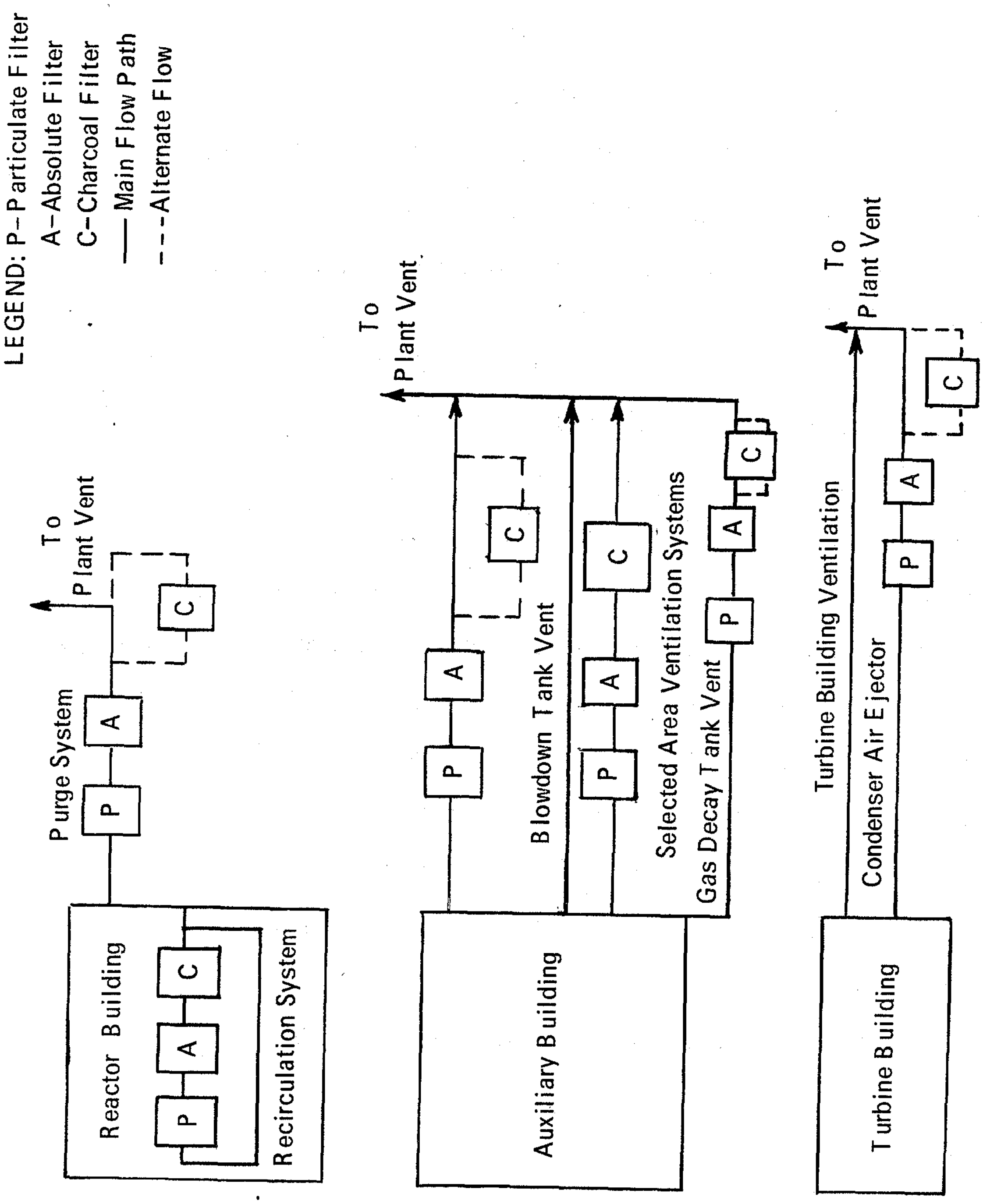


Figure 4

PRESSURIZED WATER REACTOR IODINE CONTROL SYSTEMS

APPENDIX A

ASSUMPTIONS FOR CALCULATING BWR ^{131}I DISCHARGES

1. Power level = 1140 megawatt electric [5]
2. Reference noble gas discharge rate after 30 minutes decay = 100,000 microcuries per second [5]
3. Iodine-131 coolant concentration = 0.05 Ci/m^3 [5]
4. Reactor steaming rate = 1.49×10^7 lb/hr [5]
5. Reactor steam/water partition factor = 0.012 [7]
6. Condenser air ejector iodine partition factor = 0.005 [7]
7. Reactor building iodine partition factor air/water = 0.001 [7]
8. Turbine building steam leak iodine partition factor air/steam = 1.0 [7]
9. Turbine gland-seal leak iodine partition factor = 0.1 [7]
10. Reactor building coolant leak (liquid) = 480 lb/hr [7]
11. Turbine building steam leak = 2,400 lb/hr [7]
12. Turbine gland-seal steam leak = 0.1% steam flow [7]
13. Specific volume of reactor coolant = $6.2 \times 10^{-4} m^3/lb$
14. Plant load factor = 0.80 [7]
15. Charcoal filter efficiency for iodine removal = 99% [7]

APPENDIX B

ASSUMPTIONS FOR CALCULATING PWR ^{131}I DISCHARGES

1. Power level = 1180 megawatt electric[10]
2. Fraction of defective fuel = 0.25%[8]
3. Iodine-131 concentration in primary coolant = 0.45 Ci/m^3[10]
4. Number of steam generators = 4[8]
5. Steam generator liquid volume at load = 52 m^3[10]
6. Steam generator blowdown rate = 54.6 m^3/day[8]
7. Primary-to-secondary coolant system leakage across steam generator = 0.076 m^3/day[8]
8. Iodine partition factor in steam generator steam/water = 0.01[3]
9. Iodine partition factor at condenser steam jet air ejector = 0.0005[3]
10. Iodine partition factor in steam generator blowdown tank steam/water = 0.05[3]
11. Number of containment purges per year = 4[6]
12. Primary coolant leakage to containment = 0.15 m^3/day[8]
13. Iodine partition factor for coolant leakage to containment air/water = 0.01[3]
14. Primary coolant leak rate to auxiliary building = 0.076 m^3/day[8]
15. Iodine partition factor for coolant leakage in auxiliary building air/water = 0.01
16. Plant load factor = 0.80[8]

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5. Newbold Island Nuclear Generating Station Preliminary Safety Analysis Report. Public Service Electric and Gas Company. United States Atomic Energy Commission Docket Number 50-354 and 50-355.

6. Bailly Generating Station Nuclear 1 Preliminary Safety Analysis Report. Northern Indiana Public Service Company. United States Atomic Energy Commission Docket Number 50-367.

7. Draft Environmental Statement by the U.S. Atomic Energy Commission Directorate of Licensing Monticello Nuclear Generating Plant. Northern States Power Company. United States Atomic Energy Commission Docket Number 50-263.

8. Draft Detailed Statement by the U.S. Atomic Energy Commission Directorate of Licensing on the Environmental Considerations Related to the Proposed Issuance of an Operating License to Metropolitan Edison Company and Pennsylvania Electric Company for the Three Mile Island Nuclear Station Units 1 and 2. United States Atomic Energy Commission Docket Numbers 50-289 and 50-320.

9. Sequoyah Nuclear Plant Preliminary Safety Analysis Report. Tennessee Valley Authority. United States Atomic Energy Commission Docket Numbers 50-327 and 50-328.

10. Watts Bar Nuclear Plant Preliminary Safety Analysis Report. Tennessee Valley Authority. United States Atomic Energy Commission Docket Numbers 50-390 and 50-391.

11. Zion Station Final Safety Analysis Report. Commonwealth Edison Company. United States Atomic Energy Commission Docket Numbers 50-395 and 50-305.

12. Donald C. Cook Nuclear Plant Final Safety Analysis Report. Indiana and Michigan Electric Company. United States Atomic Energy Commission Docket Numbers 50-315 and 50-316.

DISCUSSION

ESTREICH: There appear to be important differences in the criteria assumed in your paper and by the AEC. For example, the iodine partition coefficient, by AEC criteria, is 0.1 in the reactor containment and 0.0001 in the reactor auxiliary building as against the value of 0.01 that you used for both plant areas. What are the public utilities and the architect-engineers to do in this case? Whose criteria do they use?

THOMASSON: First, let me say that the difference in the containment partition factors is the difference between the ORNL paper by Dr. Binford, presented the other day, and this paper. I took the AEC number as it has been given in some of the impact statements. There is a difference between the current Oak Ridge National Laboratory value and the factor from the AEC impact statements. I went over the reason for my number for the partition factor in the auxiliary building because until I'm convinced it's not pressurized leakage I think the larger one assumed by the AEC is optimistic.

You ask, "What are the utilities and the architect-engineers supposed to do?" They should get data to prove their partition factors. I know there are some data available from operating plants. Also, I've talked to industry people here, and they know that they have seen reports on this subject, but often the reports are company-confidential. I've seen some data which may not be in a public record. I started to use the information here, but I couldn't get to a Public Document Room to make sure that it was public information. I obtained a copy of the material I used when I was at the AEC. I'm quite sure that it's public, but I didn't want to take a chance. These data give some estimates of partition factors in containment and for filter performance. I would say that they are not inconsistent with the numbers assumed here for the containment source terms. There are also data for estimating leak rates in PWR containment. However, one plant, I know, has an internal recirculation cleanup system. It also has a containment purge filter system. To my knowledge, when they had trouble with iodine releases, they had not used the internal recirculation-type containment cleanup system. They used a containment purge filter system, but never measured its efficiency. Therefore, they had to back calculate to estimate efficiency and base it on what they knew was in the containment before they purged it and what they measured at the release point.

One wonders about such calculations if they depend on effluent monitors. As Dr. Keller's paper the other day indicated, a lot of iodine from a BWR may be in an organic phase, and may not be collected in the sample. I don't know if this is also true for PWR's but we need this information.

ESTREICH: When do you think that public utilities and architect-engineers can look forward to a single agreed-upon set of criteria?

THOMASSON: Generally, you won't make a submission to the EPA. AEC has responsibility here. EPA is trying to develop some numbers they can use as a guide so they can say, "Yes; it seems reasonable. No; it doesn't seem reasonable." Because we're going to be asked, "Why do you accept the AEC's numbers on what's coming out of that plant?" Our interest is what happens to the environment. But, if you don't know the source term and how you get from it to the environmental release points, it's hard to accept a number that's been given. Therefore, we are going to look at guide values. We're probably not going to be issuing a set of acceptable guides. What we believe is acceptable may become available to the public when we develop the numbers. Nevertheless, the AEC has the regulatory authority and I'm sure you will be living by the numbers that the AEC finds acceptable.

BURNS: My question is related to the same topic. I was wondering if you could tell me what you currently use at EPA for defining "as low as practicable" when evaluating environmental impact statements? Are you using the proposed Appendix I?

THOMASSON: We're using Appendix I as a guide. It's somewhat dependent upon use of available control systems. If suitable systems are present, we feel it's "lowest practicable". If a plant has no control systems, we have problems. We'll raise the issue in the impact statement by saying, "We don't think it's "lowest practicable" because you have no systems there and we think you are going to have difficulty meeting the current guidelines." Effluent gas treatment is a solution. I don't believe that dispersion and dilution in the environment are adequate means of getting at "lowest practicable effluents". Personally, I'd like to see radioactivity controlled in the plant.

BURNS: I guess you haven't chosen to take issue to date with the AEC definition of "as low as practicable."

THOMASSON: No, we haven't. In the rule-making proceedings, our Administrator accepted "as low as practicable" and indicated that we would follow the operation and design of plants.

WILHELM: On most of your slides, I have seen stand-by filters. Where does the signal come from to start filter operation? Standby filter systems seem to be reasonable only when it is possible to detect excessive iodine concentration in the off-gas. How do you measure that?

THOMASSON: This is one of the problem areas. We should have criteria to indicate when to use these systems. For example, if, after leakage, it is found that the partition factors are worse than they were assumed, there should be criteria to guarantee that the filters will be used to meet established emission limits. The AEC has responsibility to review and accept these criteria. As long as the facility can stay within established limits, the AEC can set its own rules. I believe that equipment should be used in a reasonable manner. The FRC has said, "For any given standard or limit, the radiation exposures should be kept 'as low as practicable' below existing standards." In my viewpoint, and I don't speak for the Agency, if a plant is operating and can meet all effluent release standards without using any equipment, but could get below it if they used equipment, then operation without using equipment is not the "lowest practicable". However, since it may be within regulations, they can continue to operate without reasonable use of equipment. I think there has to be reasonableness regarding required use of the equipment; if the utilities will state their criteria for using the equipment the regulatory agencies can judge if it is indeed reasonable. For instance, a utility said, "Give us a 'number' at which point we have to use the containment purge filters. We don't want to use the big charcoal filter when it is not needed." They were told, "If you can meet occupational Part 20 levels in the containment you don't have to use the filters." Thus, the purging discharge would be well below the annual discharge limits. They were very pleased to get an acceptable guide as to when to use their filters. I think it's up to the utilities and industry to propose this type of guide. Then, people can review it, in particular, AEC can review it, and say whether or not it's acceptable.