U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTATION TO
THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: STRATEGY FOR CONTAINER MATERIAL SELECTION

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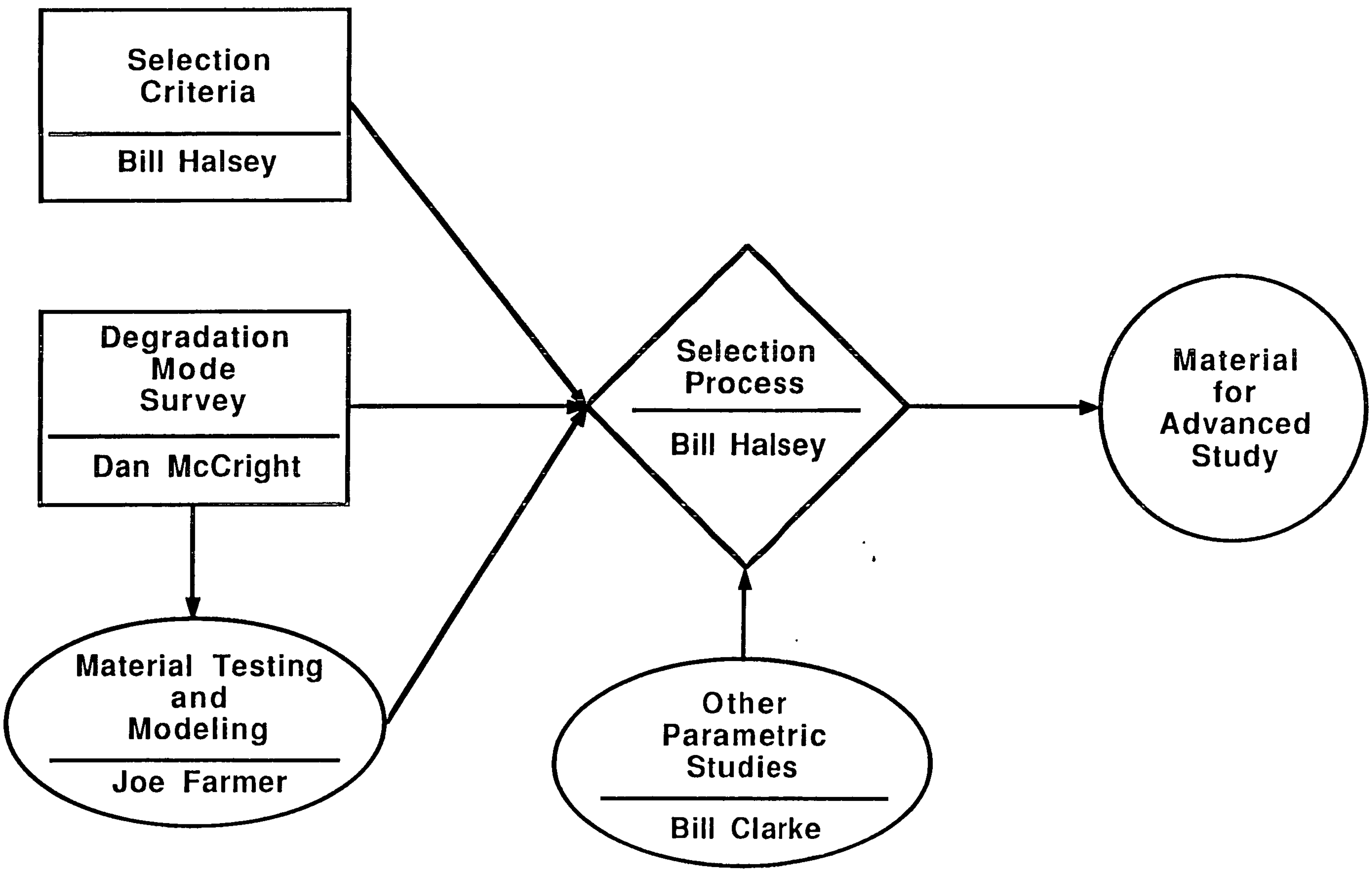
Strategy for Container Material Selection



Container Material Selection

- Develop a list of candidate materials.
- Establish selection criteria. done
- Select materials for advanced studies based on performance requirements, material performance information, and predicted waste package service environment.
- Develop material performance models and perform parametric testing in parallel with site characterization activities. Iterate with container design and performance assessment.
- Confirm or revise material selection prior to LAD based on site data and performance assessment.
- Perform long term tests and validate models (LAD on).

Brief History of Container Material Candidate Selection

- 1981 - 82
  - Program investigated repository horizons above and below water table.
  - Emphasis on thick container sections to accomodate external pressure, for below radiation self-shielding, and corrosion allowance.
  - Emphasis on carbon steels and cast irons.
- Late 1982 - Early 1983
  - Decision to locate repository above water table.
  - Emphasis shifted to thin section, corrosion resistant materials.
  - In writing of "Orange Draft" of SCP — Proposed use of bare pour canisters as disposal containers for DHLW packages.
  - Focus on 304L stainless steel as reference material.

Brief History of Container Material Candidate Selection (Continued)

- 1983
  - Survey of engineered metals and alloys.
  - 31 materials in initial survey.
  - Narrowed to 17 materials for more detailed survey (Four equal criteria: mechanical, corrosion, cost, and weldability).
  - Detailed survey recommended 4 materials for "conceptual design" study (304L, 316L, 321, and Alloy 825) (Russell, et al, UCRL 53449, Oct. 1983).
    iron-nickel SL
- 1984
  - Congress requested Program to evaluate copper and copper-base alloys.
  - Program worked with copper producing industry (CDA and INCRA).
  - 5 copper-base materials recommended by CDA, later narrowed to 3 (CDA102, CDA 613, and CDA 715).
  - Late 1984 — abandoned direct use of DHLW pour canisters, instead SF cont. to "overpack" DWPF packages.

Brief History of Container Material Candidate Selection (Continued)

- 1985 - 86
  - Copper feasibility reports prepared — reports did not reveal any "show stoppers".
  - Material Review Board comments on material issues.
- 1986 - 87
  - SCP draft prepared.
  - Austenitic candidate list scaled to three (304L, 316L, and Alloy 825) — 321 dropped because it was out performed by 316L and Alloy 825.
  - Copper candidate list remained at three (CDA 102, CDA 613, and CDA 715) — but deoxidized coppers, e.g. CDA 122, considered as a variant of CDA 102.

Brief History of Container Material Candidate Selection (Continued)

- 1988
  - SCP released as Consultation Draft (Jan. 1988) and Statutory Draft (Dec. 1988).
  - Annotated history report prepared (McCright, UCID 21472).

Austenitic candidate alloys

Compositions

Alloy	Fe	Ni	Cr	Mo	C (max)	Mn (max)	P (max)	S (max)	Si (max)	Other
304L	68 (nom)	8.00-12.00	18.00-20.00	-	0.030	2.00	0.045	0.03	1.00	N: 0.10 (max)
316L	68 (nom)	10.00-14.00	16.00-18.00	2.00-3.00	0.030	2.00	0.045	0.030	1.00	N: 0.10 (max)
Alloy 825	29 (nom)	38.00-46.00	19.5-23.5	2.5-3.5	1.0	1.0	not spec.	0.03	0.5	Ti: 0.6-1.2 Cu: 1.5-3.0 Al: 0.2 max

Mechanical Properties

Alloy (annealed)	Tensile Strength (psi)	Yield Strength (psi)	Elongation (%)
304L	70,000	25,000	30
316L	70,000	25,000	30
825	85,000	35,000	30

Compiled from ASTM specifications A 167 and B 424.

Copper-based candidate alloys

Compositions

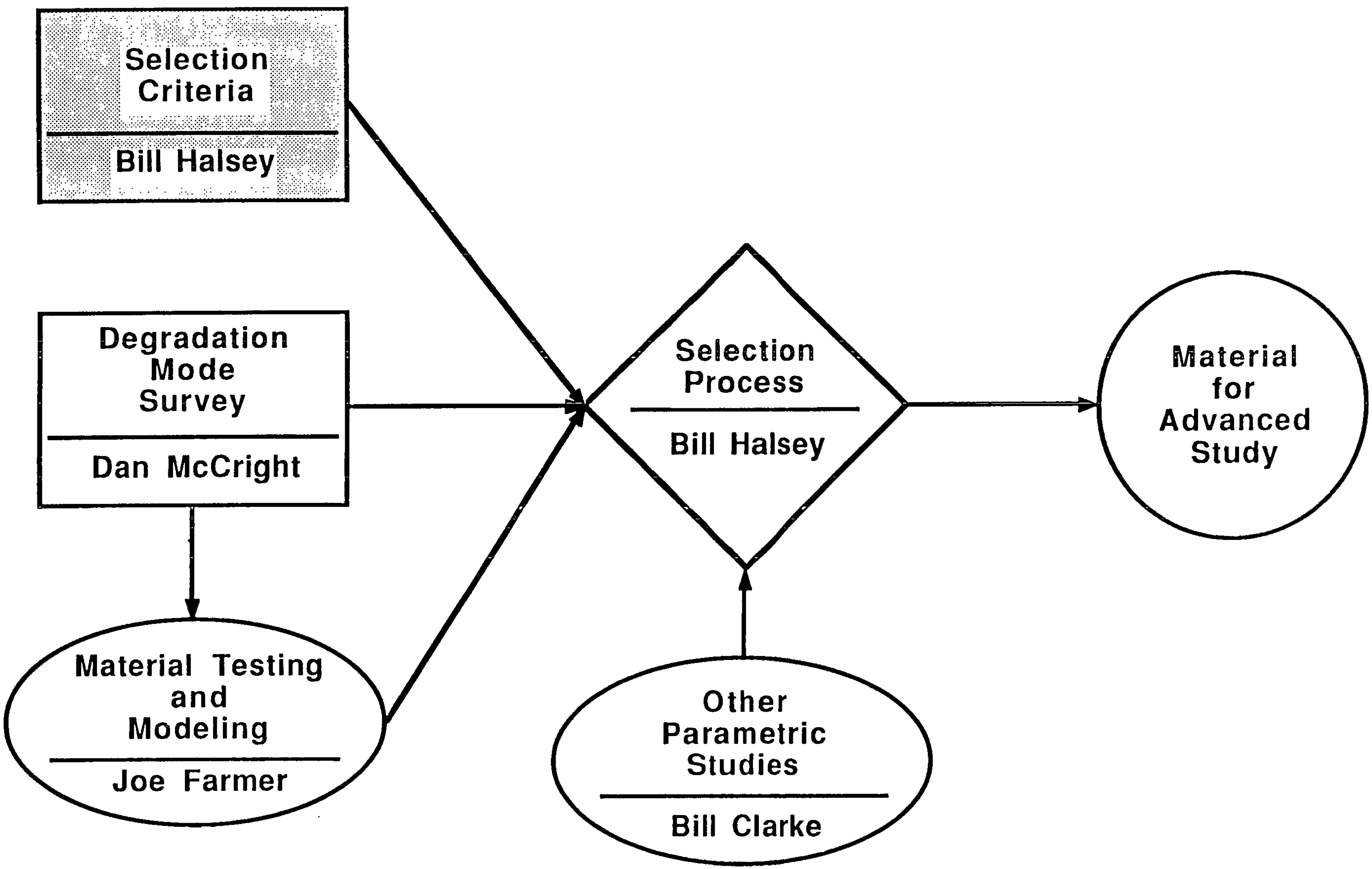
Alloy	Cu	Fe	Pb	Sn	Al	Mn	Ni	Zn
CDA 102 (OF Cu)	99.95 (min)	-	-	-	-	-	-	-
CDA 613 (Al bronze)	92.7 (nom)	3.5 (max)	-	0.2-0.5	6.0-8.0	0.5 (max)	0.5	-
CDA 715 (70/30 Cu/Ni)	69.5 (nom)	0.4-0.7	0.5 (max)	-	-	1.0 (max)	29.0-33.0	1.0 (max)

Mechanical Properties

Alloy (annealed)	Tensile Strength (psi)	Yield Strength (psi)	Elongation (%)
CDA 102	34,000	10,000	45
CDA 613)	80,000	40,000	40
CDA 715	55,000	20,000	45

Compiled from CDA Standards Handbook Data Sheets, Copper Development Association, Greenwich, CT.

Strategy for Container Material Selection



Selection Criteria

- Material independent.
- Derived from functional requirements on container.
- Establish relative weighting of criteria topics.
- Determine if candidate meets minimum requirements.
- Quantitative score to allow comparison of candidates.
- Formal peer review.

– estab quant
pass fail
– quant. fig of merit

Preliminary Selection Criteria (SCP 8.3.5.9.2.1.1)

- Which material will meet the performance allocated to the container in achieving the containment objectives (substantially complete containment under anticipated processes and events occurring in the repository)?

- Can the performance of the material under repository conditions be adequately predicted?

- Will the container material interact favorably with other components?

- Can a container be made of this material?

- Are the container material and process for fabricating it practicable?

- How can confidence in the selection be gained?

Selection Criteria – draft prepared and peer reviewed

- Divided into 34 separate criteria covering 7 topics.
- Criteria address engineering, performance, and regulatory requirements.
- Each criterion has a relative weighting factor.
- Most criteria have both Pass / Fail and quantitative score.

Material - Independent Selection Criteria

Draft Topic Areas

- PART A: MATERIAL PERFORMANCE

    A) Mechanical performance

    B) Chemical performance (corrosion)

    C) Predictability of performance

    D) Compatibility with other materials

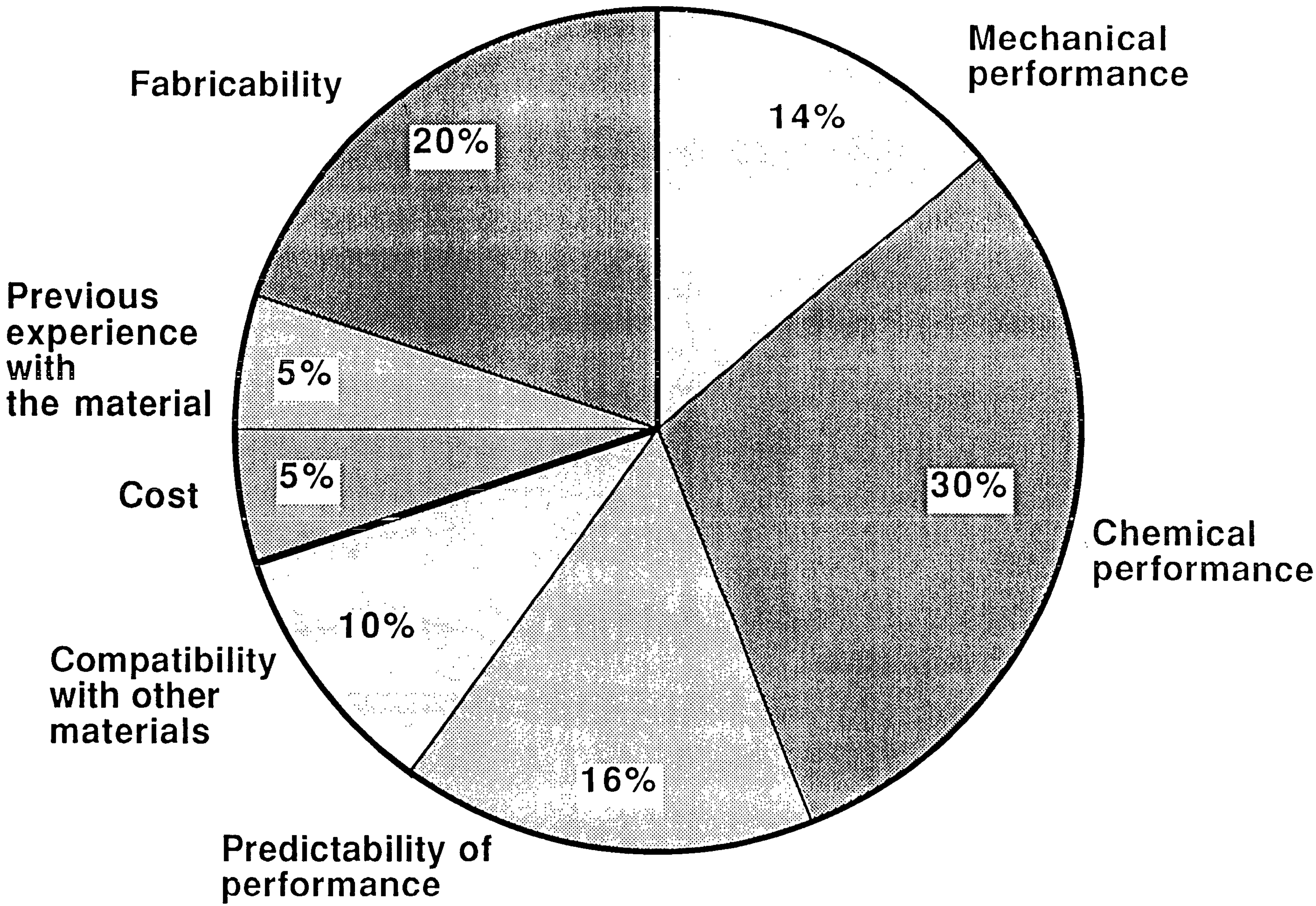
- Part B: FABRICABILITY, COST, AND OTHER CONSIDERATIONS

    E) Fabricability

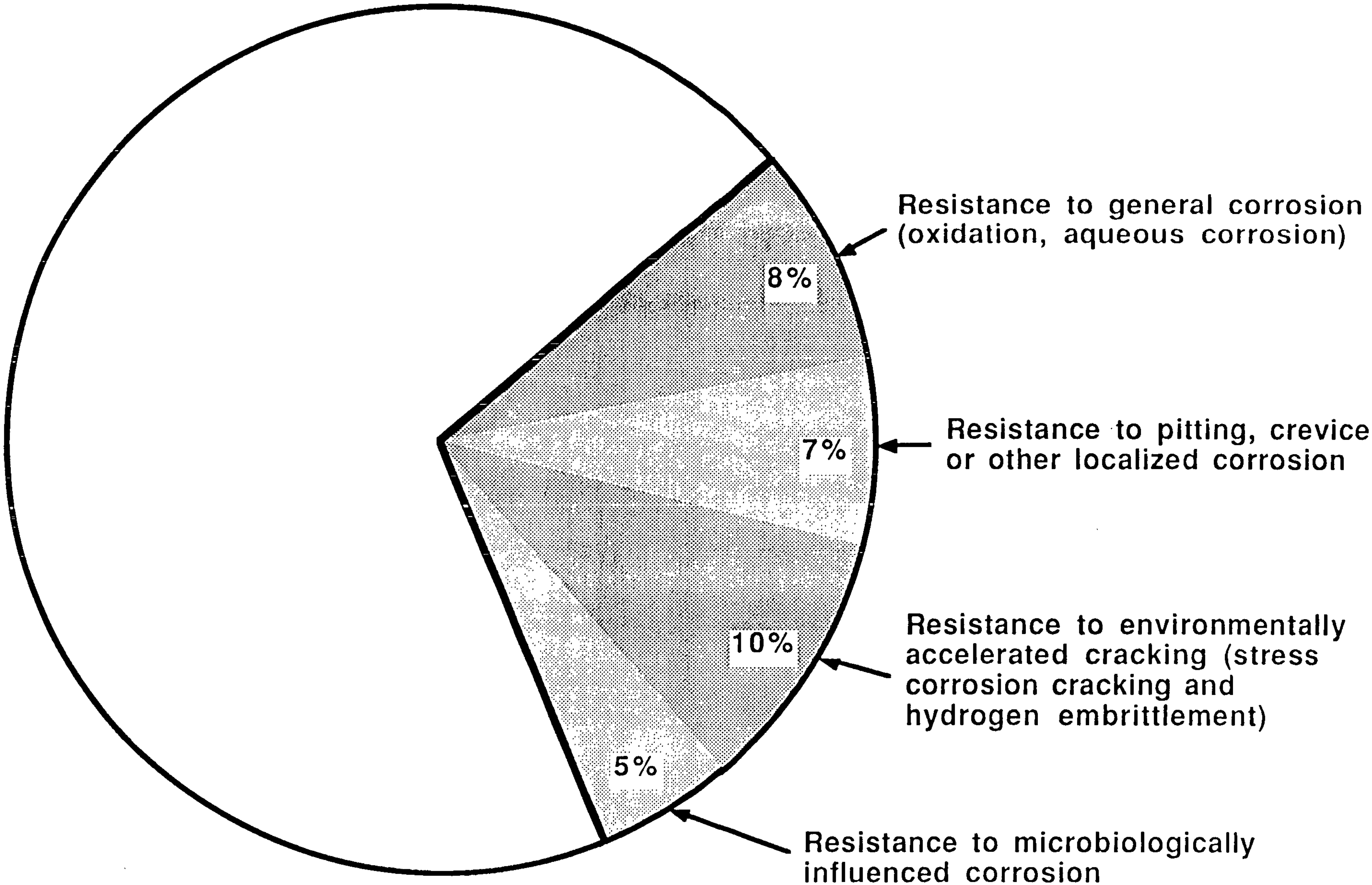
    F) Cost

    G) Previous experience with the material

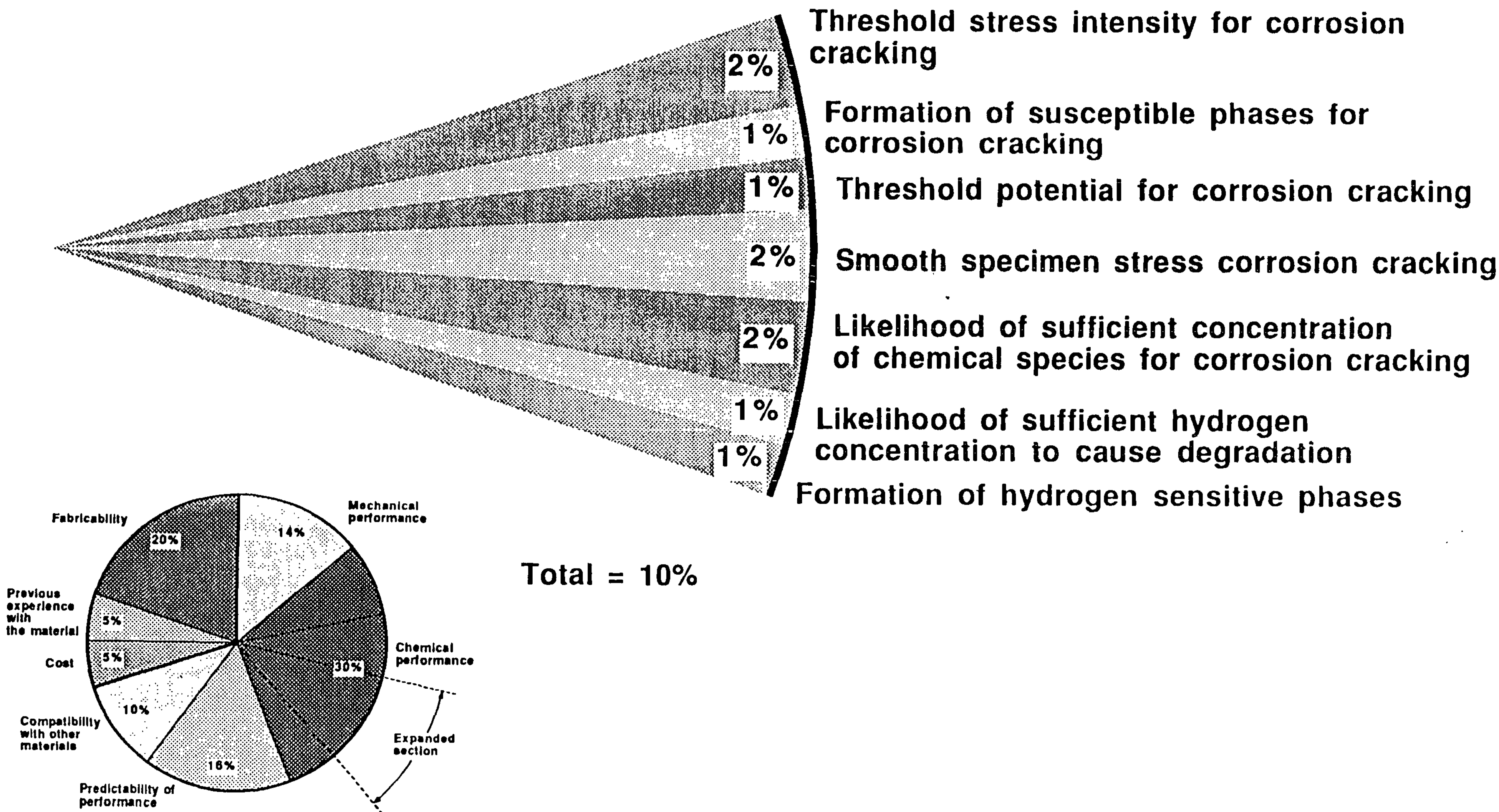
Container Material Selection Criteria (Draft)
Topic Areas



Chemical Performance Subsection of Material Performance



Resistance to environmentally accelerated cracking (stress corrosion cracking and hydrogen embrittlement)



Container Material Selection Criteria (Draft)
Detail Example

A1) Strength
Weighting Factor: 6
Parameter: Yield strength
Passing Score: Adequate/Inadequate (approx. 10 ksi minimum)
Score: Pass (5) / Fail (0)
Scale: NA

This assures adequate strength for static and handling loads. Absolute minimum values are not currently available, however typical conceptual design loads are about 1-3 ksi plus safety factor. This criterion applys at the possible 250C service temperature and must still be met after the long term aging of the material.

Container Material Selection Criteria (Draft)
Detail Example

B1) Resistance to general corrosion (oxidation, aqueous corrosion).
Weighting Factor: 8
Parameter: Time average oxidation rate (micrometers/year)
Passing score: 1.0 micrometer/year maximum

Score:	0	1	2	3	4	5	6	7	8	9	10
Scale:		100.		10.0		1.0		0.1		0.01	
Units:	micrometers/year										

This is the average general corrosion rate (from oxidation and aqueous corrosion phenomena) for the expected time, temperature, and environment for the containment period. The criterion is a wall thinning, or the sum of corrosion on the interior and exterior of the container. The passing score then allows for up to 1 millimeter of wastage from oxidation in 1000 years.

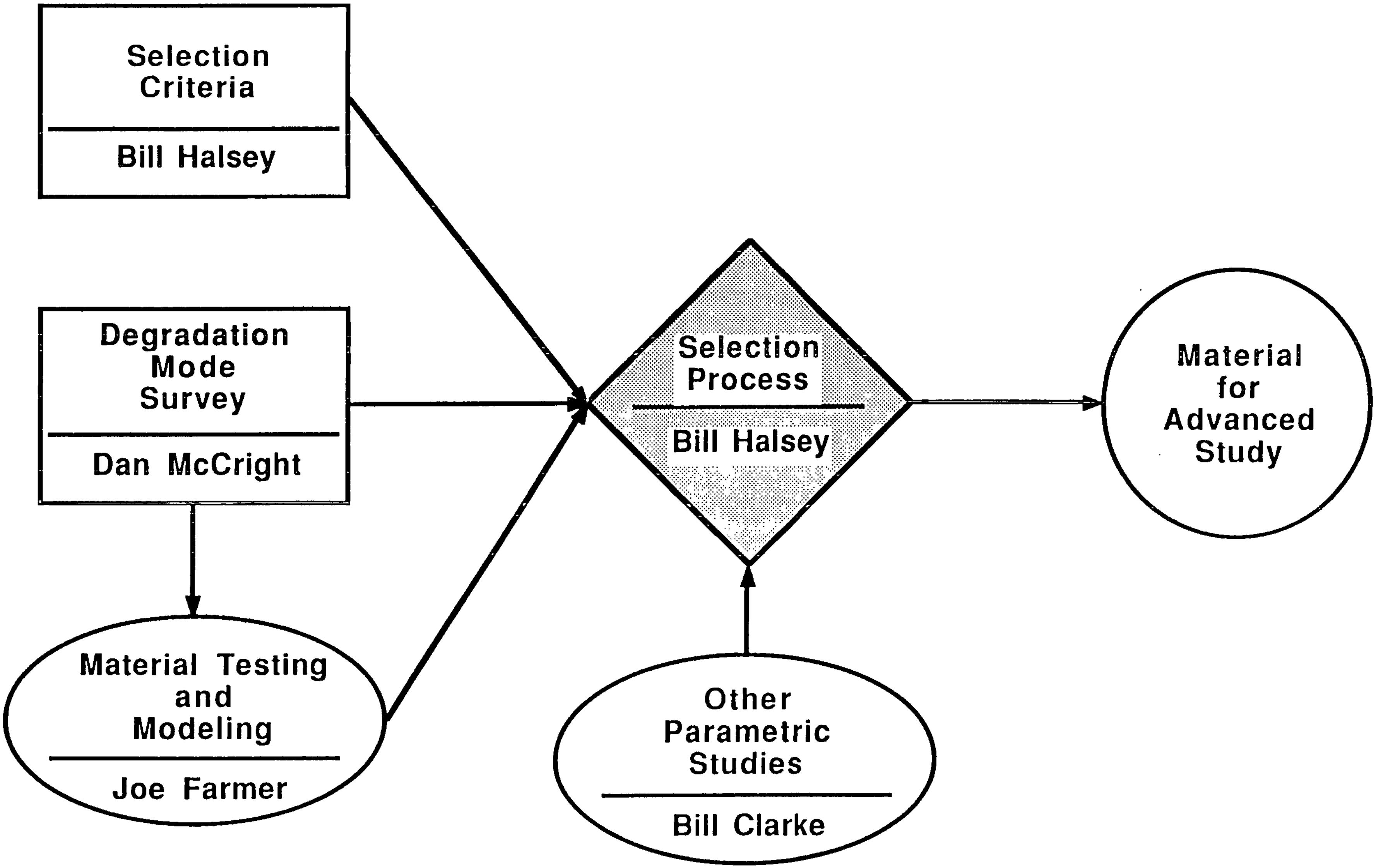
Container Material Selection Criteria (Draft)
Detail Example

B3) Resistance to environmentally accelerated cracking EAC (stress corrosion cracking and hydrogen embrittlement).
Weighting factor: 10

B3a) Threshold stress intensity for corrosion cracking
Weighting Factor: 2
Parameter: KI/KIscc
Passing score:0.7 critical intensity stress for SCC
Score: 0....1....2....3....4....5....6....7....8....9....10
Scale:1.0 0.8 0.6 0.4 0.2 0
Units: stress intensity/critical stress intensity

This is the ratio of expected stress intensity KI (due to residual stresses, applied stresses, and internal flaws), to the critical stress intensity KIscc for SCC under expected metallurgical (including the aged material), physical, and environmental conditions both internal and external. KI, KIscc, and test procedures for determining them are described by program technical documents currently being developed. The 0.7 ratio passing score is similar to ASTM Section XI limits. The KI and KIscc may have to be estimated for the selection process as the design and fabrication processes will not be finalized.

Strategy for Container Material Selection



Draft Container Material Selection Criteria Topic Areas, Weighting Factors, and Input Sources

Weighting Factor	Performance Topics	Primary Information Sources
14	Mechanical	ED, DMS
30	Chemical	DMS, Parametric tests
16	Predictability	Modeling Studies, DMS
10	Compatibility	DMS, Parametric Tests
	Other Topics	
20	Fabricability	Fabrication Studies, ED
5	Cost	Cost Studies, ED
5	Experience	ED

ED = Engineering Data
DMS = Degradation Mode Surveys

Container Material Peer Review Process

- Selection of Chairman and members.
- Advance information provided to panel.
- Peer review meeting
  - Program overview.
  - QA training.
  - Selection criteria.
  - Discussion.
- Draft peer review report prepared for Chairman by support contractor.
- Report review and concurrence by panel members.
- Revision of draft criteria considering panel comments. ← to date
- Panel responds to revisions.

Metal Barrier Selection Criteria Review Panel

- Convened, September 1988.
- Composed panel report, December 1988.
- Revision of criteria is in progress.

Sought membership to represent:

Areas of Expertise

Material degradation process.

Predictive modeling.

Fabrication and joining technology.

Component performance assessment.

Failure analysis.

Nuclear engineering practices.

Viewpoints

Academic R&D community.

Industrial R&D community.

Nuclear utility management.

Independent consultants.

Regulatory / Licensing.

MEMBERSHIP OF METAL BARRIER SELECTION CRITERIA PEER REVIEW PANEL (September, 1988)

Name	Affiliation
Dr. Robin Jones (Chairman)	Electric Power Research Institute (EPRI)
Dr. Geoffrey Egan	Aptech Engineering
Dr. Martin Prager	Materials Properties Council
Dr. Robert Long	GPU Nuclear
Dr. Richard Gangloff	University of Virginia
Dr. Roger Staehle*	Consultant / University of Minnesota

* Resigned

Container Material Selection Criteria
Peer Review

- Panel response to author questions (Author summary):

① Is this type of comparison a reasonable thing to attempt?

Summary response: Yes it is, but it must be done carefully.

② Are the criteria topics and parameters reasonable?

Summary response: For the most part, yes, but some changes are recommended.

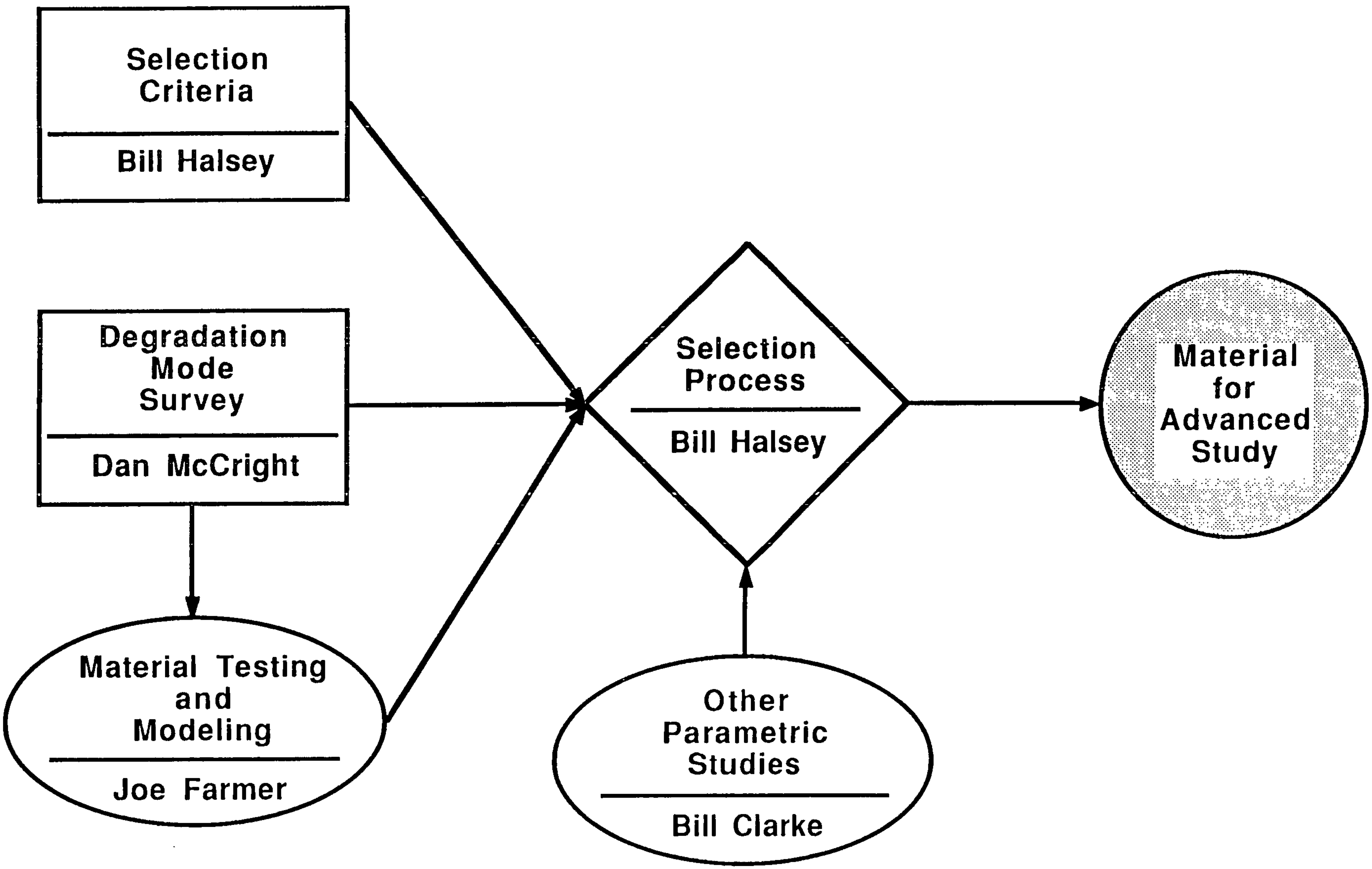
③ Has anything important been forgotten?

Summary response: Several additions are suggested.

④ Are the weighting factors and quantitative scales reasonable?

Summary response: Revision of many of the quantitative details are suggested.

Strategy for Container Material Selection



Container Material Selection Criteria (Draft)

Material Performance Topics

- Mechanical performance (14)
  - Strength (6)
  - Toughness (6)
  - Phase Stability (2)
- Chemical performance (30)
  - General corrosion (8)
  - Localized attack (7)
  - Micro-biologically influenced corrosion (5)
  - Environ-mentally accelerated corrosion (10)
    - Threshold stress Intensity for corrosion cracking (2)
    - Formation of susceptible phases for corrosion cracking (1)
    - Threshold potential for corrosion cracking (1)
    - Smooth specimen stress corrosion cracking (2)
    - Likelihood of sufficient concentration of chemical species for corrosion cracking (2)
    - Likelihood of sufficient hydrogen concentration to cause degradation (1)
    - Formation of hydrogen sensitive phases (1)
- Predictability of performance (16)
  - Predictive methods available (4)
  - Existence of long-term performance data (4)
  - Ability to generate required data (4)
  - Relative licensability (4)
- Compatibility with other materials (10)
  - Interactions with waste form (5)
  - Interactions with package environment and borehole liner (5)

Fabricability, Cost, and Other Topics

- Fabricability (20)
  - Container body fabricability (5)
    - General formability (2)
    - Product quality (2)
    - Inspectability (1)
  - Closeability of container (5)
    - General process considerations (3)
    - External process considerations (2)
  - Inspectability of closure (5)
    - General process considerations (3)
    - Detectability (2)
  - Post-closure damage tolerance (5)
- Cost (5)
  - As-fabricated container costs (2)
  - Exceptional respository handling costs (2)
  - Strategic availability of raw material (1)
- Previous experience with material (5)
  - Previous engineering experience (3)
    - Variety of applications (2)
    - Years of experience (1)
  - Existing engineering standards (2)
    - ASTM standards (1)
    - Other standards (1)